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INFORMATION

BULLETIN

European Science Notes Information Bulletin
Reports on Current
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ESN INFORMATION BULLETIN

This publication is an official publication of the Office of Naval Research European Office. It describes research that is being conducted in Europe and the Middle East.

Commanding Officer . . . . CAPT John M. Evans, USN
Scientific Director . . . . Dr. Arthur M. Diness
Editor . . . . Ms. Maureen L. Long

93-03

In This Issue...

Assessments of Oceanographic Institutes in the Former Soviet Union

by J.P. Dugan, an oceanographer currently serving as Liaison Scientist for Physical Oceanography at the Office of Naval Research European Office. Previously, he formed and directed the Field Measurements Department for Arete Associates. Earlier, he was at the Naval Research Laboratory, Washington, DC.

KEYWORDS: scientific interaction; communications; administration; travel arrangements; noncompetitive environment

INTRODUCTION

This report summarizes information obtained during liaison visits that I made to the five largest oceanographic institutes in the former Soviet Union (FSU). Primary new information obtained during these visits concerns the present structure of the institutes, the scientific personnel, and the research they presently are pursuing and planning for the future. Details are provided in Refs. 1 and 2 and in additional articles in this issue of *ESNIB*. However, the visits also uncovered some common problems that affect future coordination of projects between U.S. and FSU scientists, and these problems are discussed in more detail here.

The visits were made to the large oceanographic institutes:

- Arctic and Antarctic Research Institute of the State Committee on Hydrometeorology (AARI),
- P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences (IOAN),
- State Oceanography Institute of the State Committee on Hydrometeorology (GOIN),
- Marine Hydrophysical Institute of the Ukrainian Academy of Sciences (MHI), and
- Institute of Biology of Southern Seas of the Ukrainian Academy of Sciences (IBSS).

I was accompanied on the visits to MHI and IBSS by LCDR Larry Jendro, who at that time was the Liaison Officer for Oceanography and Environmental Systems at the Office of Naval Research European Office. In all cases, I found great enthusiasm for communication with peers in the West. This enthusiasm is partly due to scientific curiosity but, in addition, is fueled by their present overwhelming need for funding support. Unfortunately, I also found cultural, organizational, and infrastuctural impediments to the high degree of communications that are necessary in Western scientific circles.

Some of the problems are well-known and have been discussed in general-interest scientific literature in the West as well as in detail in the report of a meeting of oceanographers and national science policymakers at the Woods Hole Oceanographic Institution in 1991.[3]

COMMUNICATIONS

First and foremost, scientists in the FSU do not have adequate communications with scientists outside their institutes. This is especially apparent by the lack of electronic mail (e-mail) connections and is an important shortfall. Most U.S. oceanographic institutions use e-mail as a primary resource for their communications, both to coordinate their national and international projects and also to communicate between scientists on a daily basis.

The fundamental reason for this problem is the terrible communications infrastructure in the FSU, particularly in outlying cities. Heretofore, the only way to communicate was by telex, which is very limiting because it is too slow and indirect for normal scientific communications. Telephones (and telefaxes) continue to be very difficult to use. However, four of the five institutes now have implemented an OMNET mailbox as the result of arrangements made by U.S. institutes and agencies, so the problem of e-mail

connectivity has been overcome. OMNET was chosen as the carrier because it is the e-mail system of choice for most oceanographers in the West. The present addresses are:

Institute	**Address**
IOAN	P.SHIRSHOV
GOIN	GULEV.BOBA
IBSS	IBSS.SEVASTOPOL
MHI	MHI.SEVASTOPOL

Unfortunately, the single e-mail link at most of the institutes appears to be closely controlled, just like the telex and fax machines were controlled in the past.[4] The mailbox is accessed by only a single computer terminal, and all messages must go through a control point. This typically involves a hard copy for getting administrative approval for it to be sent. I was told by individual scientists that OMNET is not easy to use if one is a member of an "in" crowd and impossible if not. The result is that, for the average scientist, communications are not any better now than they were many years ago.

During my visits to these institutes, I found that the vast majority of scientists did not know that they had such a mail system at their institute. This is symptomatic of two problems. First is the lack of common communications among the administration and the scientific staff of these institutes. There seem to be no bulletin boards for posting messages of general information to personnel of the institutes, and the personal telephone is the only way to pass messages to anyone. The resulting lack of information is so complete and it is so endemic that it is difficult for U.S. scientist to understand.

The second problem is related. It seems that the administrators of these institutes (with some exceptions, of course) want to retain their control over the scientists. In my opinion, this is done by restricting their communications with the outside world. Outside, in this case, includes other institutes in the FSU as well as those outside it.

As an example, I asked several very senior and well respected members of the Institute of Oceanology what they thought about OMNET. In each case, they were only vaguely familiar with it, but all expressed dissatisfaction with it. One was particularly concerned about losing control and another thought personal letters were much more important. In all cases, they saw no need for speedy return of mail. The highly respected Academician Monin actually expressed the thought that all correspondence should be set aside for a week or so before replying anyway, so why the rush?

Only those scientists or managers who have spent some time in the West were familiar with the features and advantages of e-mail, and the concept of electronic bulletin boards was almost completely unknown. Most of the scientists who knew about the existence of electronic mail networks such as OMNET either did not know that their institute had a box or did not know what its name was. Many scientists asked how they could get access to their institute's mailbox or how they might get one of their own. This, of course, is a problem because the cost of many mailboxes would be prohibitive and not as easily accomplished as the single one that has been made available to some of the institutes.

Those scientists who were familiar with their institute's mailbox were concerned that they could not use it regularly because there were restrictions on frequency of use. They are told that the U.S. provides the boxes only for a specific project for which they are funded. For example, I was told that use of the IOAN box must be for World Ocean Circulation Experiment (WOCE) messages only, and if the message is not for WOCE, they do not have a need to use it. Of course it is used for some additional messages, but this is an effective method of limiting the number of them.

A number of scientists explained to me that the institute keeps the mailbox closely controlled because of the power it maintains for their administration. I really am not well enough informed to know how true this is, and I do not know the optimal approach for improving this situation. The best approach would be to supply as many mailboxes and required hardware and software as needed to overwhelm the problem, but this would be inordinately expensive. Their present sponsors in the FSU do not have the funds, and U.S. sponsors would have difficulty with the ultimate cost of accomplishing this.

Another approach might be for directors of U.S. institutes and higher officials in U.S. sponsoring organizations to address this situation. In either case, my feeling is that this will not change until a new generation of scientists gains some semblance of power in the institutes.

A singular exception in my experience is the situation at GOIN. This institute is smaller than the others, but they have two mailboxes. One of them is answered by multiple scientists, as in many institutions in the West. Those who use it are familiar with the bulletin boards and they use them. Even at this institute, though, the majority of the scientists did not know about the existence of the mailbox.

VISITING SCIENTISTS

A second problem is the difficulty of visiting scientists at these institutes, especially those in the outlying cities. Sevastopol, for instance, remains a closed city, and a visitor to the city has to depend entirely on arrangements made by the administration. When we visited, special arrangements were made to enter the city, and the only acceptable accommodations in town were on one of the research vessels. There just are no hotels and restaurants to serve outsiders. Unfortunately, they have little or no hard currency to support the travel of their scientists to foreign institutes. Thus, the scientists of these institutes cannot take part in the normal, informal comings and goings of scientists among institutions that occurs in the West.

NONCOMPETITIVE ENVIRONMENT

Another problem that particularly surprised me is the long heritage of the scientists pursuing their research in a noncompetitive environment. Historically, the scientific goals of the work in the institutes have been determined through a central planning structure; the direction and support of research of the typical scientist has been provided directly through the administration of the institute. This has resulted in a loss of productivity by some scientists. It was evidenced by a notable widespread complacency to quote work that was published in the Western literature as much as 3 or 4 years ago, rather than being concerned about what research is being done today or is being planned for next year. This is not totally disassociated from the way salaries are dispensed and, as Alexander Demchenko has said, "The little money that is available is distributed with no regard for scientific merit."[5]

Too often this has resulted in scientists pursuing their research independent of the work of scientists and institutes outside their own, even those of other institutes within their country. In my interviews, I found that most scientists knew of other scientists in their specific discipline, but they typically were not aware of what they were doing or planning to do in the near future. This should not be confused with a lack of enthusiasm for their research; in general this is not the case, except in some clear instances where apathy has set in because of the present financial situation.

ADMINISTRATIVE DIFFERENCES

The difference in the approach of scientific administration was highlighted by numerous conversations in which I attempted to explain to administrators how the scientist is sponsored in the average U.S. institution. They typically were not enthusiastic about their scientists communicating directly with others (as noted above), nor did they see the need for them to know the institute's future plans. With no previous motivation for direct interactions of their scientists with others, administrators are now struggling with the necessity to communicate with potential sponsors outside their historical ones. Their favored choice for arranging support for a new project is to engage in negotiations directly between themselves and the potential sponsor. Some administrators appear threatened by direct exchanges between scientists or between a potential sponsor and their scientists.

This shows a basic lack of understanding of the structure of our scientific institutions, with principal investigators responsible for significant levels of planning, proposal writing, and financial accounting, and the institute really providing only a support structure and community in which to work. It also displays a lack of appreciation of the need for technical exchanges and of current information on "who is doing what" in our highly competitive funding structure. They have

little idea of the workings of the proposal process or the importance that science sponsors in the U.S. place on the quality of proposals for future work. They are not aware of the importance placed on knowledge by the potential principal investigator of the status of the science and technology and of national and international programs in the specific area of the proposal. I have seen a large number of proposals for potential work but have yet to see one that is acceptable to U.S. sponsoring agencies, except where it was written in collaboration with a U.S. scientist.

An interesting sidelight is that other Western scientists who have visited these institutes have told me very similar stories. They felt that they also have attempted to explain how our system works, and that they were telling it to the FSU science administrators for the first time. The conclusion must be that the administrators either do not want to hear it or they cannot comprehend it.

CONCLUSIONS

In conclusion, I feel that I was able to make some headway on my goals for the visits, including some progress on the recommendations of the Woods Hole meeting.[3] I constructed current organizational diagrams for each of the institutes and identified specific scientists and their areas of expertise. I also was able to assess the work in specific areas; these results appear in this and a previous issue (**92-07**) of *ESNIB*. [Recent reports by other scientists on research in the FSU also appear in *ESNIB* **92-07**, **92-08**, and **93-02**. ed.] However, the organizational structure of these institutes is very different from those in the West, specifically in regard to the centralized control of the scientists and the direction of their work. It is my belief that individual Western scientists will have a difficult time obtaining really useful collaborative working relationships with individual FSU scientists in the near term. In our competitive research system, the average scientist cannot afford to take the time to attempt to work with these scientists because of the high risk of failure. This is exacerbated by our continuing limited understanding of their system of science administration, including their planning process. In the end, because the cost in time and resources is very high, the integration of these scientists into the rest of the world of science remains a job for senior scientists and science managers in the West. In my view, this cost is too high for typical individual young or mid-career scientists to undertake.

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Materials

Tribology in the Former U.S.S.R.

by Said Jahanmir. Dr. Jahanmir is with the Mechanical Properties Group, Ceramics Division of the National Institute of Standards and Technology

KEYWORDS: research institutes; metallurgy; sliding contacts; coatings; wear-resistant surfaces

INTRODUCTION

The purposes of this trip were to visit tribology research laboratories in the former Soviet Union (FSU), to attend the New Materials and Technologies in Tribology Conference in Minsk, and to explore possible collaborations between U.S. tribologists and those in FSU countries. I was accompanied by 11 senior scientists representing universities and federal laboratories in the United States. This report briefly describes research areas in the institutes that we visited and the overall topics discussed at the conference.

MOSCOW

Institute for Mechanical Problems

This institute has a staff of approximately 500; they are involved in research in four areas:

- control systems and dynamics,
- reactive gas dynamics,
- surface waves, and
- contact mechanics.

The Tribology Laboratory, headed by Dr. M. Dobychin, is part of the contact mechanics activity. It is divided into three groups and has about 14 researchers. The primary research focus in the Contact Problems Group is the development of mechanics-based models for friction and wear. This includes analysis of discrete asperity contacts, models for coated surfaces, and wear and surface fatigue models. The Friction and Surface Characterization Group is involved in experimental measurements of elastic and plastic properties of surfaces and coatings, micro- and nano-indentation of surfaces with sharp and blunt indenters, and behavior of materials under high-pressure friction. The Coatings Group is involved in deposition of thin wear-resistant films, analysis of coating thickness, development of additives containing micron-size powders, and solid lubricants for friction reduction, and test methods for characterization of coatings.

Noticeable differences between the projects in this visit compared to the visit 2 years ago include an increased level of support from industry and a more applied scope of the projects. An interesting process was demonstrated for the deposition of aluminum oxide on aluminum by plasma micro-arc oxidation. This process, which was carried out in an electrolyte with a current of 1 amp at 500 volts, rapidly produced a thick coating.

Mechanical Engineering Research Institute

This institute has perhaps the largest tribology laboratory in the world with more than 100 personnel. Professor Y. Drosdov is head of the Department of Friction and Wear. Tribology activity is divided into six sections and covers a broad spectrum of topics, including tribology of ceramics for automotive applications (silicon nitride, silicon carbide, and boron carbide), self-lubricating composites (iron, silicon, teflon), plug-lubrication, boundary lubrication, physical vapor deposition and chemical vapor deposition, laser treatment and cladding, gas plasma treatment, ion beam treatment, design of bearings and gears, tribology under extreme environments (high temperatures, vacuum, and high loads), magnetic fluid bearings,

powder lubrication, and micro-indentation for surface property evaluation.

An interesting technology, which is being transferred to industry, deals with mechanical treatment of sliding surfaces for frictional control. In this process, for example as applied to internal surfaces of cylinders in an automotive engine, the cylinder is first honed by special diamond honing sticks to achieve a desired surface finish. This is followed by mechanical transfer of a solid lubricant from a solid bar, which is rubbed against the honed surface using the same honing device. Transfer of solid lubricant to the surface of the cylinder is claimed to prolong the engine life and reduce emissions.

MINSK

Physical Technical Institute

The main focus of this institute is applied research in materials processing and manufacturing. Academician S. Astapchik, director of the institute, and his deputy stated that the focus of research has changed from serving the military to serving industry. In terms of funding, the institute used to receive 60 percent of its funds from military sources prior to the formation of the CIS countries. This funding has now been completely cut off, and only a fraction of this has been replaced with industrial funds. Current research activities at this institute include thermomechanical processes (forming, forging, hot-extrusion, etc.); finishing methods (such as ferromagnetic polishing); composites processing by powder metallurgy (self-lubricating aluminum graphite alloys for engine components); surface treatments (laser, plasma, electron beam, and ion beams); high-temperature sintering of ceramics and superconducting materials; and coating technologies (for cutting tools, turbine blades, etc.).

The Tribology Laboratory, under the direction of Dr. A. Byeli, has a staff of 15 researchers. Activities deal with wear-resistant coatings such as plasma-sprayed coatings, electron beam, and laser treatments. A unique process is ferromagnetic polishing, in which the polishing media is milled with iron to impart a magnetic property to the powder. The polishing media is then suspended by a strong magnetic field. The advantage of this process is that a hard backing plate is not required, and an excellent surface finish is obtained quickly.

Powder Metallurgy Association

This association is divided into four institutes and centers plus a large number of small companies (about 30). Professor O. Roman is director of the association, Dr. P. Vityaz is deputy director, and Dr. A. Zharin is senior scientist. Total staff of the association is approximately 2500. More than 90 percent of the operating budget is directly obtained from industry through contracts to develop or produce components. The primary focus of the Institute of Powder Metallurgy is developing and producing components (such as friction materials and porous elements for filtration) by using powder metallurgy process, flame and plasma spray coating, and CVD/PVD coatings.

The Institute of Welding concentrates on development and production of welding equipment and welding techniques. The Center for Explosive Energy is involved in explosive forming and welding techniques. The association also has an industrial plant that produces components designed and developed by the research institutes and the associated companies. The tribology projects are conducted in the Institute of Powder Metallurgy and are concerned with developing wear-resistant materials and coatings, friction materials (for brakes and clutch plates), and nondestructive evaluation (NDE) techniques for in-process wear monitoring. Two projects at this institute are unique: In one project, submicron-sized particles of tungsten carbide are injected at very high speed into metallic materials to develop wear-resistant surfaces. In the second project, the electron work function of surfaces in sliding contact is measured as an indicator of surface damage.

New Materials and Technologies in Tribology (Soviet-American Tribology Conference)

This conference was co-sponsored by the National Institute of Standards and Technology and the National Science Foundation; it was initiated during my last trip to the FSU to encourage interaction and collaboration between American and the Soviet tribologists. Total attendance at the conference was 106; 14 Americans participated.

Considering the economic problems in the FSU, this reflects a strong commitment to tribology from these countries. The following is the breakdown of the attendance from other countries: Byelarus, 30; Russia, 43; Ukraine, 9; Federal Republic of Germany, 3; Poland, 2; South Africa, 2; France, Korea, and Latvia, 1 each. A total of 75 papers and 27 posters were presented. In addition to the Plenary Lectures, talks were divided into four sessions:

- Sliding Wear Mechanisms,
- Composites for Tribological Applications,
- Tribological Coatings, and
- Characterization of Wear Surfaces and Experimental Techniques.

A booklet of abstracts from the conference can be obtained from:

Dr. Alexey Byeli
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Minsk, Belarus.

It is not possible to list all topics addressed in this short space, but the following indicate the flavor of the talks: Computer-Aided Tribological Material Design for Plain Bearings; Tribological Characteristics of Ceramic Coatings at High Temperatures; Wear Model for Alumina-Based Ceramics; Application of PVD Techniques in Wear and Corrosion; Analysis of Mechanisms of Wear of Railway Rails and Wheels; Contact of Smooth Bodies in Molecular Tribology; Elastohydrodynamic Lubrication of Line Contacts; Methods and Selection of Ceramic Materials for Cam Mechanisms of Internal Combustion Engines; Calculation of Temperature Field in Friction Contact; Structure and Wear Resistance of NiCrBTi - TiC Plasma Coatings; Powder Matrix Filled Anti-friction Materials; and Mathematical Analysis of Heat Transfer During Friction Between a Polymer Binary System and a Metallic Surface.

In general, the quality and content of the talks were similar to a typical tribology conference in the U.S., with emphasis on materials. An interesting research project was on the use of a magnetohydrodynamic technique for simulation of microgravity in casting Al-Pb alloys. This process produces a homogeneous distribution of lead in the aluminum matrix, which results in an excellent tribological performance.

GOMEL

Metal-Polymer Research Institute

The main thrust of this institute is polymer and composite materials. Dr. Y. Pleskachevsky is director of the institute, and Dr. N. Myshkin is head of the Tribology Section. A total staff of 500 work in primarily two areas, composites and tribological materials. The institute has a unique combination of basic research, applied research, and production. The production work is done in the Design Bureau, which has a staff of about 200. Its primary mission is to develop products based on research at the institute. However, only 10 percent of the production activities currently come from internal research; the rest were generated from industrial contracts for development and production of specific components.

Current activities include filters for air and liquids, noise insulation boards, wood-polymer composites, and polymer recycling. Examples of tribology research activities include liquid crystal lubricant additives, mechanics of discrete contacts, software for surface profile measurements in SEM and STM, tribology database for polymers, bench-top wear particle analysis system, electrical contact resistance measurements, self-lubricating composites, radiation of polymers to improve tribological performance, and design and analysis of artificial joints. Other activities are related to thin film coatings on seeds and fertilizers to control water absorption and solubility, special sawdust to absorb radiation, and thin-film polymer coatings for electronic applications. A useful research project deals with the development of image analysis software for analyzing wear damage. But it could have a much wider impact and a broader application, for example, in medicine for diagnostics.

KIEV

Institute of Civil Aviation Engineers

This educational institute trains engineers and managers for civil aviation. Academician P. Nazarenko is rector of the institute, and Professor N. Dmytrychenko is vice-rector. It is the largest institution of its kind, with 15,000 students, 85 professors, 200 research scientists, and 500 Ph.D.

candidates. Some of the areas include: maintenance engineers, radio electronics, automation of airport operations, flight engineers, aerodynamics, control systems, and air traffic control. The tribology activities consist of 60 faculty and scientists in areas of materials, coatings, and lubrication. Research is pursued in nano-indentation, correlation of friction with microstructural features, acoustic emission measurements during friction, plasma spray and arc sputtering coatings (ZrN, TiN, TiC) on cutting tools and engine components, and testing for fatigue, fretting wear, and sliding wear.

ST. PETERSBURG

Institute for Reliability of Machines and Structures

The institute has 17 laboratories with a staff of 450, of which nearly 100 are involved in tribology; Professor V. Bulatov is director of the institute and Professor S. Masletsov is deputy director. The tribology activities are conducted in four laboratories:

- Friction and Wear,
- Micromechanics of Lubrication,
- Industrial Wear Resistance Center, and
- Tribo-testing Center.

The first two laboratories are involved in basic research; the Wear Resistance Center and the Testing Center are involved in contract research for industry. Tribology activities include: chemistry and structure of transfer films, fretting corrosion and fatigue, polymer composites and coatings, scratch testing and acoustic emission, liquid crystal lubricants and additives, molecular theory of boundary lubrication (adsorption and effect of molecular structure), spectroscopy of surface films, generation of sound and elastic waves during friction, non-asbestos friction materials, elastomer bearings, magneto-rheological coupling, anti-friction polymeric coatings, ferro-magnetic lubricants, and bearings. Other laboratories conduct research on applied mechanics, dynamics of machines, computer-aided design, automation, surface modifications and coatings, mechanics of composite materials, and failure analysis. It is interesting to see that research is being conducted to replace asbestos-based brake materials because of health and environmental issues, similar to the work being done in the West.

GENERAL OBSERVATIONS

This visit was important in establishing contacts between American tribologists and those in the FSU countries and discussing possibilities of collaboration. We were all impressed with the large number of tribology research activities and the emphasis that is placed on tribology in the research institutes. In general, the quality of experimental research does not appear to be as advanced as in the West because of the limited availability of advanced analytical tools. However, theoretical analyses being conducted seemed to be on par with the West. We were impressed with the well-trained research staff who were bright and eager to collaborate with their counterparts in the West. Everyone we met expressed a strong interest in establishing joint research. The following activities seem to me to be of special significance for establishing collaborations:

- exchange of published research information (i.e., publications)
- publication of papers from the U.S. in Russian tribology journals
- exchange of scientists and guest researchers
- exchange of databases and materials for evaluation
- direct funding of collaborative research projects
- frequent joint conferences on tribology to stimulate further contacts.

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Personal Impressions of the Status of Tribology in the Former Soviet Union

by Irwin Singer, Surface Chemistry Branch, Chemistry Division, Naval Research Laboratory, Washington, DC

KEY WORDS: ion implantation; analytical equipment; surface modification; coatings; deposition

INTRODUCTION

The New Materials and Technologies in Tribology Conference in Minsk and laboratory visits in Moscow, Minsk, Gomel, Kiev, and St. Petersburg provided a significant overview of tribological research in the former Soviet Union (FSU). I gained a good perspective of the status of tribology and the style of scientific reporting of tribologists, and I was able compare the scientific approaches, equipment sophistication, directions of materials research, and potential technologies used in the FSU with those in the West (including Japan). My specialty is surface analysis and surface modification, with a bent toward scientific aspects of friction and friction films, and I report primarily on these topics. I've tried to reference examples of work reported at the conference or during visits The conference proceedings (containing many of the papers) will be published in a future edition of *Trenie i Iznos*, the *Soviet Journal of Friction and Wear*. However, the conference abstracts do not list the scientists' institutions, so I simply refer to the authors and their cities.

GENERAL OBSERVATIONS

First, a few general observations are in order. To say that tribology is alive and well in the FSU may be an understatement. I have the distinct

impression that there are more scientists and engineers interested in tribology in the FSU than perhaps in all the West! And, tribologists are important people in the FSU. Heads of several institutes that we visited are tribologist [Vladimir Bulatov, director of the Research Institute for Reliability of Machines and Constructions in St. Petersburg and Rector Pavel Vasiljevich Nazarenko, Institute of Civil Aviation Engineers in Kiev] and three of Nazarenko's predecessors were tribologists. The conference had many Ph.D. students presenting their thesis work, so it appears that the production of tribologists goes on, despite the (fairly recent) cut in state support for science and engineering.

The style of scientific reporting by tribologists matched what I've seen by FSU physicists. Analytical formulations of tribological processes were presented, even where neither the basis nor the application were clear. There were several good critical assessments (experimental) of prevailing models. For example, V.G. Kuznetsov, Minsk, presented a critical assessment (and ultimately a rejection) of the "accepted" Garkunov-Kragelsky anodic dissolution model for the basis of non-wear mode of Cu vs steel in glycerine. Few talks, however, made general comparison with tests performed by other workers under related conditions (allowing the audience to generalize the results). Moreover, only a small percentage of FSU authors referred to work in the West. (However, the reverse is also true; Western authors often ignore work from the FSU.)

I would say that FSU tribologists have less advanced equipment than Western scientists and engineers. I was somewhat surprised, however, to see many microcomputers (IBM-compatible 286, 386, and 486s and Macintoshes) at FSU laboratories. While I doubt that the scientists have as easy access to microcomputers as we do in the West, those that need them apparently are able to get them. I saw or heard of their use:

- to control and acquire data from tribometers, scanning electron microscopes (SEMs), scanning tunneling microscopes (STMs), and other mechanical microprobes; and
- for computerized intelligent tribology systems that purport to predict machine service life.

All the laboratories visited had conventional analytical equipment, like SEMs and X-ray diffractometers. We didn't see any ultra high vacuum (UHV) surface analytical equipment, like Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS or ESCA), or secondary ion mass spectrometry (SIMS); however, their use was reported in many studies. And, some groups in the FSU have STMs and atomic force microscopes (AFMs).

We also saw several unique apparati for investigating tribological properties of surfaces:

- An electron work function monitor (technically, with surface capacitance measurements) that appears to "follow" the macroscopic friction behavior. However, the basis for this behavior isn't established. [A. Zharin et al., Byelorussian Powder Metallurgy Association, Minsk]
- The "MICRON," a computerized sclerometer and continuous indenter with a scanning system that gives topographical and mechanical (hardness, elastic, creep) properties (hardness...) of thin layers [Institute of Civil Aviation Engineers, Kiev]. This device combines friction measurements and profilometry with a mechanical microprobe.

COATINGS AND SURFACE TREATMENTS

Coatings and surface treatments are a major area of interest in tribomaterials world-wide. Plasma sprayed coatings, formed in water as well as in air and vacuum, were represented. PVD and/or CVD hardcoatings are being studied at most FSU tribology institutes, and, as in the West, attempts are being made to commercially exploit the process for decorative coatings as well as for wear resistance (e.g., for cutting tools). One coating technique that I saw in most laboratories is the arc deposition process. Invented and patented in the former U.S.S.R. in the 1980s, it is still under development, but may not be advancing as rapidly as in the West.

Surface modification by energetic beams is an alternative (and often an adjunct) to coatings for protecting surfaces. Surface modification by the three most common techniques—by lasers, electron beams (EBs), and ion beams—was discussed at the

conference. Lasers were used to melt powders to make antifriction bushings and inserts [N.G. Baranov, Kiev]. Laser treatments were compared with EB treatments (below the melting point) for improving the wear resistance of low- and medium-carbon alloy steels [E.V. Konopleva, Chernogolovka, Moscow,]. EB processing was also investigated for forming TiO_2 and other coatings on Ti alloys [I. Pobol, Physical-Technical Institute, Minsk]. Several presentations were made on ion implantation for improving wear resistance (of tool steels, mainly), accompanied by discussions that attempted to correlate processing, phase formation, and wear behavior. Another talk [I.G Romanov, Nizhniy Novgorod, Russia] compared the techniques of continuous and the more-recent pulsed-ion implantation. However, implantation effects are no better understood today than they were 8 years ago (in the East or West). A hybrid ion implantation technique, ion-beam-assisted deposition (IBAD), which combines ion implantation with PVD coating deposition, is being investigated experimentally and theoretically (by molecular dynamic simulation) at the Physical Technical Institute in Minsk by A.V. Byeli.

One application of ion implantation that may be of interest was presented by M.I. Guseva, St. Petersburg, Russia. They conducted both laboratory and sea tests on ion implantation treatment of sterntube bearing rubber inserts. Normally, these rubber inserts fail by the rubber fracturing and spalling after 4000-5000 hours. Laboratory tests on inserts mimicked the failure mode and showed that ion implantation increased wear life by ×4. Implanted inserts were installed on three atomic-powered icebreakers of the Minsk Shipping Company in 1985, 1986, and 1987. On the icebreaker *Siberia* (1986), the implanted inserts didn't fail; on the icebreaker *Russia* (1987), the implanted inserts gave the best life, so far: 16,000 hours.

Finally, two non-high-technology surface modification treatments caught my attention. With one, thick (mms), hardened, and wear-resisting layers are formed by explosion injection of hard-particles into metal surfaces [S. Usherenko, Byelorussian Association of Powder Metallurgy (BAPM), Minsk]. With the second, a simple, nonabrasive finishing treatment was found to improve the wear resistance of cylinder liner piston rings [L.M. Rybakova, Moscow]. Improvement was related to the composition and structure of the altered surface layer.

FILMS

Surface topography and films—how they form and how to analyze them—are of great interest to tribologists concerned with understanding and controlling friction. Many of the conventional (AES, XPS, SIMS, SEM) and more-recent (STM) surface analytical techniques are being used. I did not see much potentially "forefront" research from these approaches, except, perhaps, from the computer simulation of real contact zone of solids based on STM data [S.A. Chzhik, Gomel]. A potentially useful technique, developed at the Metal-Polymer Research Institute (MPRI) in Gomel, is the theory and application of surface profilometry by using SEM.

It is well recognized that the lubricity of a lubricant is often derived from soluble additives. These additives interact with surfaces to form slippery films, often only a monolayer thick. Several institutes have been investigating liquid crystals as lubricant additives. MPRI (in Minsk) researchers are selling liquid crystalline compounds as additives for a wide range of lubrication chores, from machinery to human joints. E.L. Aero and his group at the Research Institute for Reliability of Machines and Constructions, St. Petersburg, are investigating the friction reduction and life extension of sliding couples lubricated by liquid crystal additives.

A second area of surface film research is "selective transfer," in which ultra-low friction layers are developed and "wearless" sliding occurs at high-speeds. (I heard that this concept of "selective transfer" has been debated in Russia for years, but it is not well understood.) Discussions of enhanced lubricity and wear stabilization were often couched in terms of "self-organized layers." I never did get a fully satisfactory explanation of this effect; however, I take it to mean a third body at the interface (protective film or an altered layer), which apparently produces a drastic change in the wear mode.

FRICTION

Microscopic aspects of friction is one of the forefront topics in tribology. Atomic-level friction of liquid and solid surfaces can be measured (by STM and AFM) and calculated (e.g., by molecular dynamic simulations). I heard no reports of computer simulations of friction and only two experimental investigations:

- Computer simulation of real contact zones of solids based on STM data [S.A. Chzhik, Gomel]
- Surface films generated during sliding against epoxy were analyzed by AES and STM; "wearless" friction was associated with a highly ordered molecular structure with constant lattice close to 1.9 [A.G. Kosakov, Shachty, Russia].

ENVIRONMENT AND ECOLOGY

After all the dismaying reports of ecological disaster in the FSU I'd seen on television, I was happily surprised to see institutional concern for environment and ecology. Conference abstracts refer to: lubricants with ecological "acceptance" and "purity" and less squeaking from ecologically clean polymeric brake material. BIMP in Minsk has developed materials and manufacturing processes for antifriction and structural composites based on wood waste. Waste-reducing and ecologically clean, wood-polymer composites exploit properties of wood such as self-lubrication, elasticity, vibration, and corrosion resistance. MPRI in Gomel has developed a sawdust to collect Chernobyl-contaminated surface soil. They have also developed:

- composites based on wastes of chemical industries and unrecyclable plastics;
- coatings to protect grains and seeds; and
- fertilizer coatings that are doped with nutrients and act as diffusion barriers.

COMMERCIALIZATION

All of the tribology research that we saw, including the few forefront fundamentals programs, took place within institutions whose stated purpose included technology transition, i.e., to develop engineering materials or machines for "improving the country's economy or machinery for industry,..." We saw many products and processes that the laboratories were interested in selling, licensing, or investigating further with dollar-paying collaborators. Products include the ecological products mentioned above and a variety of data control and acquisition software for analytical equipment (SEM profilometry, STMs, and AFMs).

CONCLUSIONS

Tribology in the FSU has great depth and scope; moreover, a huge number of scientists and engineers are trained in tribology. The lack of fundamental work in the microscopic aspects of friction may be due to a scarcity of advanced computers or specialized equipment, or maybe I just didn't visit the appropriate institutions or departments. [By design, the meeting announcement and visits may have excluded fundamental tribology performed in departments of Physics or Chemistry.] Most institutions have been hurt financially by the collapse of the Soviet Union. However, they do have the brain power and the engineering orientation essential for developing products and processes. This might enable the laboratories to find financial support and also to effectively transition technologies, once the needs are established.

Mathematics

Mathematical Modeling and Representing Objects in 3-D Space—Freeform Curves and Surfaces '92

by Gregory M. Nielson, Computer Science and Engineering, Arizona State University, Tempe, Arizona.

KEYWORDS: modeling; visualization; parametric methods; implicit methods; "patches"

INTRODUCTION

The Mathematisches Forschungsinstitut Oberwolfach, located in the Black Forest village of Oberwolfach-Walke, Federal Republic of Germany (FRG), was the site of the Freeform Curves and Surfaces '92 ("Freiformkurven und Freiformflaachen") meeting held 14-28 June 1992. The institute receives support from the Volkswagen Foundation. which allows for very reasonable fees to be charged to the attendees.

Computer-aided geometric design (CAGD) emerged in the early 1970s and has grown into a vital and active area of study and research. Today it enjoys the support typically accorded any scientific discipline: workshops, seminars, textbooks, and journals. Much of CAGD is concerned with the development of the science and technology for the computer-aided design, analysis, and production of three-dimensional (3-D) objects (such as cars, airplanes, and telephones). This meeting was the fifth in a series of workshop/conferences on CAGD held at Oberwolfach, with the first being held in 1982. Participation at Oberwolfach meetings is by invitation only, and these invitations are highly regarded. This generally leads to very high quality talks on the latest and best research in an area. The total attendance was about 60; about 40 presentations were made. The attendees were primarily from Europe and the U.S.

Rather than report on all the presentations, I have picked a representative sample to report on, hoping that my selection and comments will convey a sense of what occurred at the meeting in a more compact and easily obtained manner. A list of abstracts for all talks is available from:

Institute Office
Mathematisches Forschungsinstitut
Oberwolfach, Albertstrasse 24
D-7800 Freiburg/Breisgau
Federal Republic of Germany

At the end of this report, I have condensed various bits and pieces gathered from the speakers (and others) into a list of problems and activities to convey a sense of what is happening in the area of CAGD.

COMMENTS ON FOUR SELECTED TALKS

Modelling and Visualization With Implicit Surfaces—Wolfgang Dahmen, RWTH Aachen, FRG

Throughout the development of CAGD, two distinct approaches to representing surfaces in 3-D space have been followed:

- Parametric methods with a representation of the form (X(u,v), Y(u,v), Z(u,v)), which map a 2-D domain containing (u,v) to 3-D space; and
- Implicit methods, which define a surface as a set of points {(X, Y, Z) such that F(X,Y,Z) = 0}.

The parametric approach is associated with spline functions and has been quite successful for the

general representation and design of free-form surfaces. The implicit approach is philosophically more closely related to the concepts of Constructive Solid Geometry (CSG) and Solid Modeling. Both approaches have long lists of pros and cons. One of the most detracting aspects of the implicit approach is the lack of techniques for designing free-form surfaces. Valiant attempts have been made over the years, but no real successes have been obtained to date. This presentation describes the most recent attempt. The work is encouraging and interesting. The authors develop techniques for matching user-specified normals and positions to points of a triangulated net in 3-D space. They use implicit patches that have algebraic defining functions of degree 3. Some rather impressive images were shown; I believe this is the first public announcement of these results.

Topological Design of Sculptured Surfaces—Alyn Rockwood, Arizona State University

The genus of an object reveals the number of holes that it has. A sphere has genus zero and a donut has genus one. The genus is a fundamentally important topological property of an object that should be consistent with any mathematical representation. For example, the genus of a mathematical model of the surface of a human skull should be the same as the skull it is attempting to model. Often, many topological properties are taken as byproducts in the design and representation process. This is not the case for this work. Rockwell makes the point that topology is primal geometry and reports on a new surface design method based on a "marked" polygon. The marked polygon captures the topology of the mappings from a polygon to the sculptured surface. Three different techniques for obtaining a parametric map of a surface with predescribed genus are given. One of the most interesting examples is the mapping of the hyperdisk to a double torus.

The whole character of this work is very interesting, from the involvement of an actual sculptor (Helaman Ferguson) with real machined works of art to the novel and intriguing use of geometry and topology. I suspect we will see more on this in the future.

Embracing CAGD—Constraints on Industrial Application as Seen by the German Automotive Industry—Werner Dankwort, BMW; Reinhold Klass, Mercedes Benz; Burkard Woerdenweber, Hella

This was a rather unique session held one evening after dinner. Werner Dankwort representing BMW, Reinhold Klass representing Mercedes Benz, and Burkard Woerdenweber representing Hella (a German company that produces automobile head lamps) gave a rather informal presentation on the current usage of CAGD techniques and methodology in their respective companies. Both Klass and Dankwort have attended and given presentations at all of the four previous meetings and so, to most of the attendees, their material was more incremental and perceived as a current update about ongoing projects. In addition to their own research and development projects, both Klass and Dankwort have been for many years very actively involved in the establishment of standards for the description and distribution of geometric data. This is an area that seems to get more attention in Europe than in the rest of the world. They seem to take this whole problem much more seriously than most. I think that most people would consider the problem of standards as being an important topic that should be dealt with, but it is not a heavyweight research problem and so, unfortunately, most are not really very interested.

An interesting feature of this presentation was a one-page sheet of problems that the presenters felt needed attention by this scientific community. One person jokingly asked if they would be willing to issue a research contract based on these problems. The audience laughed and the presenters were silent. Here are the problems that were presented:

- Problem 1: edge detection from scattered point data (application - digitizing, returning FEM [finite-element method] data)
- Problem 2: surface approximation from scattered point/normal data (application - digitizing, returning FEM data)
- Problem 3: specific - trimmed surface for corner blend; general - filling n-sided patch with trimmed surface maintaining edge

conditions (ϵ-GC^n condition) (underlying surface exceeds corner blend for milling purposes) (application - "shape preserving" surface generation)

- Problem 4: smooth cross-edge connection between trimmed surfaces (ϵ-GC^n condition) (application - "shape preserving" surfacer generation)
- Problem 5: modelling techniques for b-rep. shells (application - "shape preserving" surface modification)
- Problem 6: offsets of b-rep. shells (application - thick plates, milling)
- Problem 7: rational offset surfaces (application - thick plates, milling)

Barycentric Coordinates for Convex Polytopes—Joe Warren, Rice University, and Tony DeRose, University of Washington

Bernstein polynomials have been important from the very beginning of CAGD. The parametric versions of these polynomials are called Bezier curves in CAGD and can be represented as $\Sigma(i = 0, n)\ B_i\ C(n,i)\ t^i\ (1\text{-}t)^{n-i}$, where the point in 3-D space, B_i, is called a control point and is used to shape the curve. The notation C(n,i) is used for the combination of n taken i at a time. The concept of a Bezier curve is of theoretical interest and practical value. Generalizing from one variable to a bivariate domain leads to methods for surface representation and design. Generalizing to volume domains gives rise to techniques for animation and deformation (morphing) of 3-D objects. In this presentation, the authors are interested in generalizing to a general convex polytope domain. The basis functions $B_i(t) = C(n,i)\ t^i(1\text{-}t)^{(n-i)}$ can be obtained from the binomial expansion $[t + (1\text{-}t)]^n = t^n + \ldots + C(n,i)\ t^i\ (1\text{-}t)^{(n-i)} + \ldots + (1\text{-}t)^n$. The quantities t and (1-t) can be viewed as the barycentric coordinates of an arbitrary point in the domain. This observation is the key to their approach; all that is needed is a representation of barycentric coordinates for convex polytopes. The authors develop a nice representation based on some very reasonable definitions and assumptions. Within certain restrictions, they show that this representation is unique. Several examples are discussed. We point out that these barycentric coordinate representations are closely related to nodal functions used in FEM. The results of this work could lead to improved techniques for solving partial differential equations over convex polytopes. It is a starting point.

CAGD RESEARCH ISSUES

I conclude this report with a "top 10" list of "what is happening in CAGD". The list is not meant to be definitive. Some items overlap and the length and level of detail varies considerably, but it should help the nonspecialist by defining the area, and it allows the material of the present meeting to be seen in a larger context. Much of the research mentioned in this list is focused toward and culminates in the tenth and most encompassing item on the list. It is a vision of the future application of CAGD techniques in concurrent engineering and manufacturing within the context of virtual reality. This is an extremely exciting and potentially very useful application area.

Three-Dimensional Object Representation from Scattered Data

Consider a cloud of empirical 3-D data points provided by a scanner and the subsequent task of inferring the geometry and topology needed to obtain a mathematical representation of the surface(s) implied by these data. This is a difficult problem partly because there is no implicit neighborhood information in the data and because the data are subject to measurement error. Even if topological information is inferred or somehow provided in the form of a triangulation of a reduced set of points, the resulting parametric scattered data interpolation problem still remains a challenging research problem. The first techniques to address these problems have recently appeared, but they will have to be made more robust and be extended to generate mathematical representations consistent with CAD/CAM systems now in use. The immense value of these algorithms for processing scanned data and 3-D data reconstructed from the registration of multiple camera images ensures that this area will see a lot of attention in the future.

Non-Uniform Rational B-Splines (NURBS)

A variety of parametric surface patches have been used in CAGD. We hear a lot about NURBS these days, and it is generally accepted that this class of parametric surface patches is rapidly becoming a de facto industry standard. Actually, NURBS have been around since the early days of computer graphics since they are a direct result of applying B-splines in the context of homogeneous coordinates. One of the nice features about NURBS curves is that conics can be represented exactly.

As NURBS become more accepted it will be important to include NURBS as nodes in a CSG (Constructive Solid Geometry) context for object description. For this to happen, problems related to design, manipulation, and display must be addressed. For example, in CSG it is important to be able to answer the basic question: given the point (x,y,z), is this point in the object or not? This easily stated question cannot be easily answered for NURBS-bounded objects at this time. Other basic operations that have to be available to incorporate NURBS in a CSG framework include surface to surface intersection, surface offsets, and automatic mesh generation. In addition to the normal control points associated with B-splines, NURBS have additional parameters consisting of the weights in the denominator that must be specified by the user. In some situations it would be desirable to have techniques for automatically selecting these values, thereby removing the heavy burden from the naive user. Users of modern workstations have grown to expect realistic quality renderings, so if ray tracing is to be used, then extremely effective and robust algorithms for computing the ray intersections must be developed.

Scattered Data Modeling

One of the major contributions of CAGD has been the development of methods of extracting the relationships inferred from empirical or simulated data. This is sometimes called scattered data modeling. The 1980s saw a very rich and broad development in the case of bivariate scattered data interpolation techniques. However, most of the interesting cases today (such as finding the pressure on an aircraft wing, or assessing mineral depositions in a geological feature), involve 3-D domains and domains restricted to a 2-D manifold in 3-D space. For some methods, extension to 3-D may merely involve the appropriate 3-D redefinition of a distance function. But in general, the elevation is not so trivial. For example, in 2-D the number of triangles in a triangulation of a convex hull is fixed, while in 3-D even a simple cube can be "triangulated" into 5 or 6 tetrahedra, which lends ambiguity to algorithms attempting to find an optimal triangulation. Other research work in this category includes higher (than 3-D) domain data, restricted domain (surface on surface and manifold) data, and vector and constrained range data and methods for dealing with very large (millions or billions) point sets.

Interrogation

Although strikingly realistic computer-generated images are possible today, the quality and technical smoothness of a surface cannot be ascertained from the conventional illumination models used, regardless of how accurate or how high a resolution is used. Anomalies in the surface may not be detected until a physical model is examined, and this is too late. So-called interrogation techniques can minimize the possibility of this inefficiency. Reflection lines, Gaussian curvature texture mapped onto a surface, and focal surfaces are examples of promising techniques that can reveal problem areas in a surface at the design stage. Further development of these and related techniques will be of considerable value to the overall problem of surface design and description. It would also be interesting to extend this concept to the case of volume data and volume renderings. In general, when one is trying to learn something by visual inspection through computer-generated images, the more tools the better.

Implicit Versus Parametric Representation

Two distinct approaches to representing surfaces in 3-D space have been followed throughout the development of CAGD—parametric and implicit; these approaches have been described earlier in this report.

A subproblem within the parametric camp is whether to use triangular or rectangular patches.

Rectangles are relatively easy to deal with because they are just one variable process done twice (tensor products or Boolean sums). There are real problems, however, in trying to represent certain objects by using only rectangular patches. Triangular patches can be useful here, and they arise naturally in other problems, but adding triangular patches to a CAD system complicates matters considerably. Allowing two types of patches requires two sets of procedures for dealing with these patches (rendering, offsets, intersections, etc.). Although it could be argued that a rectangular patch is just two triangular patches, it is unlikely that we will soon have a system based only on triangular patches, given the strong momentum behind rectangular patches. This debate will also continue.

Data Visualization and Other Uses of CAGD Techniques

Data visualization is an emerging area that uses computer-generated images to allow scientists to extract knowledge and understanding from experimental or simulated data. Properly prepared images using color, texture, transparency, and a myriad of other techniques can convey a tremendous amount of information about a data set in a very short period of time. The technology and expertise of CAGD can significantly aid in the development of these techniques. A prime example is the development of techniques for representing the surfaces that separate 3-D flows. Understanding flows is fundamental to understanding many basic phenomena in science. Flows occur at all scales, from molecular beams, to mesoscale oceanic flows, to galactic winds. The usefulness of topological methods for understanding 2-D flows has been established, therefore, topological methods based on separating surfaces will be of interest and value.

Representing surfaces is well understood by the researchers of CAGD, but it is unlikely that published algorithms on surfaces will directly apply to the representation of separating surfaces. Having CAGD researchers work in conjunction with CFD researchers is a plan that has a high probability for success. This is but one example of where the expertise of CAGD could be extremely beneficial. As many scientific disciplines move into 3-D modeling (made possible with the increases in computing power) it becomes more and more important that they have the mathematical means of modeling and representing objects of 3-D space.

Parallel Computing in CAGD

As with many areas of science and engineering, CAGD has a need for and can benefit from the use of parallel and distributed computing. High dimensions and large data sets carry heavy computational burdens. In some areas of CAGD, the requirements of interaction place a special need for speeds that can only be accomplished through parallelism. Realistic renderings of 3-D objects, interrogation methods, and other visualization techniques have this property. Other than a few examples of special hardware for some of the basic algorithms of CAGD, the work in parallelism specific to CAGD has and will most likely continue at a pace and direction very similar to other areas.

CAD/CAM Technology

As CAD/CAM evolves within the mutual influence of existing manufacturing and engineering processes, it is more and more important to develop and utilize standards. One important area for this is the distribution and exchange of geometric information. For example, the headlight manufacturer must have from the automobile manufacturer a usable form of the geometry for the cavity that will contain the headlight. To the extent that CAD/CAM technology depends on the techniques of CAGD, these standards need to be considered from the standpoint of both theory and practice. On the other hand, in some cases real-world CAD/CAM systems dictate the direction that further CAGD research will take. Feature-based design, n-sided patches, and blending techniques are some examples of this type of research.

Foundations

Several key concepts are unique to or have originated in CAGD. These concepts must be placed on a firm mathematical foundation, not only to promote the maturation of CAGD, but also to enable these concepts to influence other areas. This premise can be more fully explained by using

the example of geometric continuity. The basic idea of geometric continuity originated with ν-splines, which are curves that have individual component functions that are only C^1, yet the curves have continuous curvature. They can be re-parameterized so as to be C^2 without changing the shape of the curve. So, from a geometrical point of view they are really C^2, it just happened that the way the curve was represented made it not C^2. If a curve can be changed from C^1 to C^2 without changing its graph, then the mathematical definition of continuity is deficient in this context. Geometric continuity, as developed in CAGD, could possibly be the proper concept, but it needs deeper underpinnings and mathematical footing. Other fundamental topics of CAGD that have the potential to become part of the lay scientific knowledge base include aspects of optimal triangulations, solvability of multiquadrics, and organizing formulations such as blossoming. These are only samples from a much larger list.

Virtual Manufacturing

To some people, a CAD system consists of a collection of procedures performing the various tasks needed to do effective design and representation of a 3-D object. Providing a user environment is brushed off as an interface problem to be solved by the implementing programmer, but this indifference to the interface does not negate the importance of the coherence between the various procedures. The sum is only greater than the parts if the system is put together with careful attention to how the system is to be used. Manipulating geometry in an interactive environment to design a 3-D object is not a simple matter, but with the advent of virtual reality it can be very exciting. Of course, just stating that virtual reality will take care of the interface issue is just another sidestep of the interface issue. However, once we progress past the hyperbole and gadgetry of virtual reality and these techniques (and associated hardware for 3-D input and 3-D display) become ingrained in the methods we use to solve problems, CAD/CAM within a virtual reality environment will lead to effective design and production collaborations. Some researchers have coined the acronym ViCE (Visualization in Concurrent Engineering) to describe these futuristic scenarios where geographically isolated designers, engineers, manufacturers, and economic consultants interact with some product as it is taken through a virtual evolution from idea to finished product on the warehouse shelf.

Team-based cooperation is the centerpiece of Concurrent Engineering. The key to good concurrency in design is improved team communication and visualization, which sharpens analysis results, benefits the analyst, the team members, and in the end—the product being designed. Some of these techniques are basic user-interface graphics while others involve high-performance multidimensional image rendering and animation. Yet others are slightly beyond current state of the art. Graphics and visualization have moved swiftly over the past 20 years, from the first mouse to virtual reality. The excitement continues as these and more powerful paradigms are applied to scientific analysis and design optimization. I am convinced that the strong research being done in CAGD today will help to bring these visions to fruition in the near future.

Oceanography

Physical Oceanography in the Ukraine: The Marine Hydrophysical Institute

by J.P. Dugan and Larry Jendro. Dr. Dugan is an oceanographer currently serving as Liaison Scientist for Physical Oceanography at the Office of Naval Research European Office. Previously he formed and directed the Field Measurements Department for Arete Associates. Earlier, he was at the Naval Research Laboratory, Washington, D.C. Larry Jendro was the Liaison Officer for Oceanography and Environmental Systems at the Office of Naval Research European Office. Following his retirement from active military service, he currently is Chief, Science Branch, Ice Operations Division, U.S. Coast Guard Headquarters.

KEYWORDS: remote sensing; scientific cooperation; dynamic processes; research vessels; instrumentation

INTRODUCTION

The Marine Hydrophysical Institute (MHI) in Sevastopol is the largest oceanographic institution specializing in physics in the Ukraine. It is one of the several very large marine-related research institutes in the former Soviet Union (FSU) and, along with all other scientific organizations in the FSU, it is undergoing considerable change. This report is both a summary of information learned while visiting the Institute at the invitation of the director, Dr. Valery Eremeev, and a commentary on the oceanographic research infrastructure in the former Soviet Union.

This Institute is venerable, having been first organized in 1928. It also is very large, having grown in size and importance during the Soviet Union's many years of emphasis on science. Research focuses entirely on the physics of the oceans. The Institute is made up of a central core of about 850 scientists and administrators housed in two buildings directly on the harbor at Sevastopol, a branch of some 120 people at Katseveli, and another branch of 200 people at Odessa. Of the total staff of 850, 450 are technical staff, and of these, 100 are classified as having a first-level Doctorate, 100 as Aspirants, and an additional 70 as Doctoral Candidates. The Katseveli Branch is discussed in some detail because we had the opportunity to visit it. The Odessa Branch is further distant and emphasizes ocean acoustics; its connection with the Institute in Sevastopol seems to be rather loose.

In addition, a Technical Design Bureau of about 300 additional people is located in Sevastopol. This group has recently been removed from MHI and organized as a separate institute. Finally, there is a research center in Guinea, Africa, of about 30 people at present. It was constructed and maintained by the Soviet Union as a demonstration/teaching science facility in exchange for copper export concessions to the Soviets. Many of the MHI scientists we talked with had spent time there, but now it has lost its priority for scientists and funding.

The political and financial situations for MHI are very difficult. The Ukrainian government must have some difficulty in supporting this large a scientific establishment, which is focused on research not obviously necessary for their short-term survival. Worse yet, Crimea has also discussed independence from the Ukraine, so the present situation is very unstable. Funding for work in the Institute in the past was obtained directly from the Academy of Sciences in Moscow, so the director and senior administrators are very busy attempting to cement new relationships in Kiev and elsewhere. The primary sources of funding are the Ukrainian Academy of Sciences and the State Science Committee. Even if there is no further splintering of states, the support from the State Science Committee is uncertain for next year, even for the next

quarter. The present annual budget is 60M rubles, with no hard currency for costs outside of the area. Fuel is still available locally, but the lack of hard currency restricts research cruises to the local area.

ORGANIZATION

The director is Academician Valery Eremeev, whose expertise is in radionuclides in the sea. Deputy directors are Prof. Vladimir Efimov, Dr. Vitaly Ivanov, and Dr. Gennady Korotaev. The latter has additional responsibilities as the Director for International Affairs, and he was the official host for our visit. He is the head of the Department of Ocean Dynamics but previously washead of the Department of Remote Sensing of the Ocean, so we had most direct interactions with these groups. Table 1 lists the major departments and their heads. The individual responsibilities of these various departments is not clear to us, and we found a significant amount of overlapping work.

Department of Ocean Dynamics

Dr. Korotaev provided a short summary of work in this department. A large fraction of effort in the years 1984 to 1991 was on the Atlantic Tropical Ocean. In cooperation with the State Institute of Oceanography in Moscow, department personnel undertook 25 surveys of this area, obtaining more than 6500 water density profiles. A major effort has been involved in management of these data. One specific analysis task has been a frequency-wavenumber decomposition of the data to determine the dispersion relations of

Table 1. Departments of the Marine Hydrophysical Institute

Department	Head of Department
Theory of Waves	Prof. Leonid Cherkesov
Oceanography	Prof. Nicholas Bulgakov
Shelf (Ecosystem) Dynamics	Dr. Vitale Ivanov
Ocean Dynamics	Dr. Gennady Korotaev
Remote Sensing	Dr. Vladimir Kudryavtsev
Applied Hydrophysics	Dr. Gennady Khristophorov
Contact Methods of Investigation	Dr. Nikolay Karnaushenko
Air/Sea Interaction	Prof. Vladimir Efimov
Nuclear Hydrophysics	Prof. Acad. Valery Eremeev
Dynamical Statistical Modelling	Prof. Igor Timchenko
Optics and Biophysics	Acad. Valery Belgaev
Turbulence	Dr. Nicolas Panteleev
Automatization (DBMS)	Dr. Vitaly Gaysky
Experimental Investigations	Dr. Sergey Boguslavsky
Complex Methods of Investigations	Dr. Leonid Koveshnikov
Soviet-Guinea	Dr. Eremeev

any propagating waves and, thereby, to determine the principal mechanisms responsible for the variations. The scientists interpret the first energetic peak in the spectrum as the first baroclinic Rossby wave that propagates westward at 15 cm/s. A second energetic peak that appears to be caused by meander of the northern counter current is interpreted as a standing topographic wave. In addition, Dr. Korotaev has written a monograph available only in Russian on theoretical models of Rossby waves (*Theoretical Modelling of Ocean Variability*, 1988), and his group is making comparisons of the models to the tropical Atlantic data.

Dr. Sergey Bulgakov of this department provided a briefing on research on the circulation in the Black Sea. This enclosed body of water is especially interesting because it is large (much larger than the Rossby radius of deformation) so that the effects of Earth's rotation are important, and it is much deeper than the sill at the outflow through the Bosporus Sea so the deep water circulation is limited. Because there is no convection in winter, the deep water is not exchanged, and there is a scientific issue associated with the resulting chemistry of the deep water. An additional interesting scientific issue is whether the observed cyclonic circulation in the upper layer is driven primarily by wind stress or by buoyancy forces from outflow of water from the large shelf in the northwest part of the sea. In one study, a simple theoretical model (box model with 1-D linear boundary jet) has been exercised to select parameters of interest for a laboratory experiment. This experiment is being planned at the Woods Hole Oceanographic Institution in conjunction with Dr. Jack Whitehead. Also, an eddy-resolving circulation model of the Black Sea is being exercised on a computer (486 clone) by Dr. S.G. Demyshev. It is a Bryan-Cox model with 18-km grid spacing and 21 vertical layers. They expect to use three 1984 surveys of the density structure of the Black Sea for assimilation into the model to test its predictive capability.

According to Dr. N. Shapiro, other Bryan-Cox models of circulation are being exercised for the tropical Atlantic (15°N, 10°S) and the North Atlantic (0-50°N). These apparently are not eddy resolving and must be highly diffusive, as they have only 1° spatial resolution. They are being used to study subduction processes and the motions associated with intrusions of water that flow off of large shelves, such as the one in the northwestern portion of the Black Sea. These are subjects of high interest presently, but it is unclear to us whether eddy processes can be neglected in this process. No definitive results are available.

The Department of Ocean Dynamics includes a Laboratory for Remote Sensing and Data Analysis headed by Dr. Vadim S. Suetin, who has worked with passive microwave data for sea surface temperature and with sea color data for water identification and circulation patterns. Their first work in this area was with Cosmos 1151 satellite, which was launched in 1980 with a microwave sounder, an infrared (non-scanning) sensor, and a visible spectrometer. They continued work in the area with data from the Coastal Zone Color Scanner on Nimbus 7, a U.S. satellite, with the objective of obtaining a global map of ocean color. There are known problems with the calibration of this sensor, and the results we saw (on a computer monitor since they have no color plotter) are not nearly as impressive as a National Aeronautics and Space Administration (NASA) product that has been distributed widely in the oceanographic community in a poster format. They are continuing to work on color data from InterCosmos 21, since it had 12 visible and near-infrared channels. They are working specifically on atmospheric correction algorithms, and hope to work with NASA on data from the upcoming SeaWiFS sensor that is expected to be launched in the future. They expect to obtain a license with no difficulty, having spoken with Gregg Mitchell of NASA headquarters, but they foresee problems in obtaining the required downlink if they are to do any near-realtime analyses of the data.

Department of Remote Sensing of the Ocean

Dr. Vladimir Kudryavtsev, the head of this department, has published occasionally in Western literature and traveled to the West, so he was familiar to us. He personally arranged all interviews and accompanied us throughout the visit to MHI. He knew of our keen interest in their general knowledge and status of research in remote sensing, so he gave us a comprehensive tour of his laboratories. His department is made up of two laboratories and one group of scientists.

Their interest in remote sensing has been driven by the need to assimilate observations of the ocean into models for understanding physical processes and for predicting the density structure into the future. They originally planned that the source of the remotely sensed data was to be Soviet satellites. Some work has been done with both Soviet and American satellites, namely infrared data for sea surface temperatures. However, they are attempting to cope with the present political situation wherein they have no expectation of future launches of Russian satellites (even more unlikely, Ukrainian satellites), and they do not have the contacts to work in the international community with satellite data that are available there

This is an area of specific interest to us, and it is a potential subject for collaborations between MHI and Western scientists in the future. The data stream from satellite ocean sensors is almost limitless, there is more of it than the scientists typically can analyze in detail. Consequently, there is a place for additional scientists to analyze data for additional locations such as the Black Sea. It does require that the satellite sensors be turned on over the Black Sea and that the appropriate interested scientists have access to the data in a timely way. The universal knowledge in the discipline can only be advanced by cooperative research between these scientists and scientists from the U.S. and Europe where numerous satellite systems are either currently in space or are being planned for future launches.

The two laboratories in this department are the Laboratory for Analysis of Satellite Images, headed by Dr. Gennady Grishin, and the Radiometric Laboratory, headed by Dr. Terechin Pustovoitenko. They pursue experimental and theoretical studies on the physical processes that occur at the ocean surface and in the thin upper-ocean layer. These processes include surface wave dynamics, wave breaking, and the processes that determine the vertical structure of the top 1 m of the water column. The purpose is to understand the spatial structure exhibited in images of the ocean surface with the types of sensors noted previously. This department has focused mainly on temperature and roughness measurements from ships, aircraft, and satellites.

Dr. Grishin has published considerably (in English) the research in his laboratory on the interpretation of infrared images of the surface. He has worked with many of the early Russian cosmonauts and has extensive experience with satellite photography. The work is interesting and was roughly equal to what was being done in the U.S. at the time, but we found little that really is unique or different in this work. Dr. Grishin has an interesting monograph of photographs of ocean phenomena that were taken by cosmonauts that is similar to the NASA/Navy book *Satellite Oceanography*, published some years ago in the U.S.

Dr. Semen Grodsky outlined extensive experimental and theoretical work on the refraction and breaking of surface waves in horizontal current shear. He showed us an interesting example of synthetic aperture radar (SAR) data obtained with the Almaz platform in an experiment in the Gulf Stream off the U.S. East Coast. They are working with Dr. Robert Beal of the Applied Physics Laboratory of The Johns Hopkins University on analyzing these data. Finally, Dr. Stanichny of the Radiometric Laboratory is working on multi-wavelength algorithms for inverting infrared measurements of surface temperature from ship, airborne, and satellite sensors, and in the interpretation of the data in terms of processes at the sea surface. They have an interesting optical sensor system for counting the number and size of breaking waves. This work is several years behind similar work currently in progress by Dr. Bryan Kerman of the Canada Centre for Inland Waters.

Department of Applied Hydrophysics Research

The emphasis in this department, led by Dr. Khristophorov, is on the effects of inhomogeneities in the wind and the ocean, specifically of internal waves, on the surface of the ocean—particularly their effects on surface waves. They have a very large range of instruments for making observations in this area, including a laser slope meter (similar to the West Coast Canadian system of Dr. Bryn Hughes some years ago), current meters (Weller rotor type), thermistor chain, and ocean "internal wave" meters based on the Russian line sensor technology of some years ago. These instruments have been used in experiments from the research tower at Katseveli, and he plans to continue this work at the tower in the near future. This work seems to be continuing with little interaction with

Western researchers in this area in recent years. We did not hear clear objectives for this work, and the instrumentation now is far behind current technology in the West.

Department of Wave Theory

Academician Cherkesov is very well known for his extensive work on theoretical models for wave propagation in stratified, rotating fluids. He has written a long list of monographs on results of this work, and some of it has appeared in the Academy of Sciences Journal *Oceanology*. This subject includes internal gravity waves in simple layers, with bottom topography, with nonuniform density and current profiles, and with rotation. Wave generation by moving ships and atmospheric disturbances have also been studied for these different conditions and in steady and transient situations. Included in their list of studies are models of long surface gravity waves, barotropic and baroclinic tides, and effects of topography such as simple models of ridges, shelves, and seamounts. In total, a truly bewildering number of theoretical situations have been solved analytically.

Dr. Cherkesov heads a department of some 23 scientists pursuing continued work in this area. The department is unique in the world to our knowledge. It is almost purely academic and appears to have very little interaction with scientists either within or outside the institute. We could see no comparisons between predictions based on these models and observational data, as the discipline might be pursued in the West. It is not easy for us to understand how or why the work continues in this mode.

Turbulence Department

Dr. Nikolay Panteleev told us that the objective of his work is to understand the energetics of dynamic processes in the ocean (from the molecular to synoptic scales) with manifestations on ocean resources. This wide range of scales defines a rather broad charter, with work ongoing on mechanisms for the generation of fine structure, mesoscale features, double diffusion phenomena, hydrodynamic stability, the interaction between large and small scale processes, and turbulence. He is interested in the effects of fine structure on biological fields, biological blooms, and patchiness; the spread and dilution of pollutants; the development of experimental equipment; and the safety of surface ships and submarines. In all, a very long list of topics. Unfortunately, in our view, they seemed to be short on published results. We expect that this is due to their poor turbulence instrumentation. We did not see their instrumentation, and Dr. Panteleev seemed unwilling to discuss it, but we understand from other interactions that it all is suspended from the research vessel and therefore the data typically are badly contaminated by ship and cable motions.

Dr. Panteleev is an experienced expedition chief on their large research vessels and has been involved in intercomparisons of U.S., Russian, U.K., and Canadian microstructure sensors in the last year. Again, we were unable to see any results of analyses of these data.

Department of Interaction of Atmosphere and Ocean

Dr. Efimov told us that this department has four laboratories:

- Laboratory of Small Scale Interactions of Atmosphere and Ocean,
- Laboratory of Global Interaction,
- Laboratory of Wave Disturbances, and
- Laboratory of Studies in the Tropical Atlantic,

with a total of 45 scientists. Scientists of this department also were involved in the SECTIONS cruises in the tropical Atlantic mentioned previously, and he was enthused about a monograph on the results that is about to appear (in Russian). His group is involved in planning a follow-on set of observations called ROCC (Role of the Ocean in Climate Change), and this apparently is a continuing involvement with the State Oceanography Institute in Moscow. There is a planning document, but a copy could not be made available to us. We were not able to determine just how this effort would interact with the World Ocean Circulation Experiment, which involves many oceanographers and countries in the rest of the world, nor how they would accomplish it with the present difficulty in obtaining ship time.

Department of Oceanography

Academician Bulgatov told us that this department is made up of the Laboratories of Physical and Chemical Oceanography and a small group working on bottom relief. The primary goals of the department are to study seasonal, annual, and interannual variations in large-scale thermohaline and hydrochemical fields. They have worked in the tropical Atlantic, the Black Sea, the Mediterranean, and the Caribbean. Dr. Bulgatov is a co-author of the well known monograph *Synoptic Eddies in the Ocean*, which was published in 1980 as a result of some of the POLYGON experiments carried out in the 1970s.

This work was associated with the early Soviet observational grids of current meter moorings and conductivity-temperature-depth (CTD) stations that ultimately ended up in the joint U.S. — former U.S.S.R. POLYMODE experiment off the U.S. East Coast in the early 1980s. He also has authored a monograph on circulation in the Caribbean that has recently been published, and he showed us a publication that essentially is an atlas of sound velocity profiles calculated from the stations obtained during the Tropical Atlantic SECTION observations. He said additional monographs containing the data on the Caribbean and Black Seas would be available in the near future, and wondered if we might be interested in having them translated. We do not understand the value in having these available, and therefore we have no good reason to recommend this.

Department of Shelf Hydrophysics

Dr. V. Ivanov said this is a new emphasis of the Institute, with research focusing on coastal and shelf zone dynamics. The goal apparently is to quantify the range of variations that occur on the shelves and to understand mixing processes on the shelf and the interaction with deeper water at the shelf edge. They have worked in the Black Sea, which is almost nontidal, and on the shelf of Guinea, which has significant tides; thus they now have some experience in both domains. He maintains that the dynamics can be very different in the two domains, and we agree with this conclusion.

He told us about the Black Sea Project, including the construction of an oceanographic database (called "Black") on this body of water. It apparently includes all bottle and CTD stations (more than 100,000 stations) and current meter and geophysical data collected in almost 100 years of observations. There also is an atlas of internal wave data being assembled, but what this consisted of was not clear to us. In a discussion of the mechanisms for ventilation of the thermocline in the Black Sea, he reviewed some plots of data collected during a survey of the shelf along the Crimean coast with CTD stations, seven current meter moorings, and measurements from the Katseveli tower. The primary variation seemed to be due to shelf waves of about 10-day and 4-day periods and to inertial waves.

He would like to make a case for mixing of surface waters into the thermocline by winter cooling of shelf water on the large Northwestern Shelf, but the details were not clear to us. He also felt that they had established clear evidence of ventilation of the thermocline during a cold weather overturning event in the center of a mid-basin eddy (this was published in 1984).

Department of Automation of Ocean Research

This department has the task of developing new instrumentation for use by the other departments in the Institute. It works in conjunction with the Design Bureau in Sevastopol for the production of these instruments. Apparently, this bureau once was part of the Institute, but it has separated recently. There are three laboratories, and the total effort was claimed by Dr. Gaysky of the department to be the leading sensor development laboratory in the FSU:

- Laboratory of Measurements and Computing Systems
- Laboratory of Methods and Facilities for Measuring Currents
- Laboratory for Automatic Systems for Measuring Marine Medium.

This department was responsible for developing the ISTOK series of CTD profilers, with number 7 now in use and number 8 currently in development. The CTD has long been considered a basic instrument for physical oceanography research, but these ISTOK instruments (along with the AIST

CTD of the Shirshov Institute in Moscow) have had a checkered history. They have not been considered to be as accurate nor reliable as similar instruments in the West. Intercalibration tests during international cooperative experiments have brought out several anomalies that had not been previously discussed publicly by this group.

In addition to the vertical profiling CTD, the department has developed a series of towed instruments for obtaining CTD profiles while the ship remains underway. The cable-towed GALS instrument (MHI 9201) is in modification number 3, and it can make profiles to 200 m depth once every 2 km while the research vessel is underway at 12 knots. It meets the need for rapid underway surveys of the mesoscale and sub-mesoscale physical structure of the upper ocean that is recognized by all oceanographers. It carries a CTD, a two-frequency optical attenuation sensor (480 and 600 nm), and a fluorescence sensor for chlorophyll-a, providing the capacity for rapid observations of the biogeochemical structure of the water column together with the physical structure. The hydrodynamic shape of the vehicle is very different from either the SeaSoar or Batfish vehicles used in the West for the same purpose. However, it appears to be much more rugged, as well as rather unrefined. There currently is interest in developing new towed profiling systems of this type at many oceanographic institutes in the world, and it would be interesting to see a comparison of the relative performance of this system with the two western designs.

The department also has worked with the Design Bureau on a series of inexpensive sensors with small housings, such as current meters, CTDs, and sound velocity sensors. In fact, there is a perplexing series of separately identified CTDs with slightly different specifications. They all appeared to be relatively new, and some were claimed to be very reliable but inexpensive so that they could be used by numerous vessels (with their suggestion being a fishing fleet). One interesting and different feature of the CTDs is that they separately measure sound velocity by using a sing-around principle, whereas in the West the sound velocity usually is calculated from measurements of temperature, salinity (actually conductivity), and pressure. The directly measured sound velocity is then analyzed in conjunction with the value of sound velocity calculated from the simultaneously measured pressure, temperature, and conductivity, and the difference between the two values provides an estimate of the data quality. This is a good idea to assure the operability and calibrations of the sensors, but it was not clear to us whether this was necessary because of a problem of some sort, or rather just a convenient check on the performance of the instruments. Unfortunately, the sensors still seem to have limited dynamic range, apparently due to the continuing use a 12-bit digitizer.

FACILITIES

The main laboratory facility comprises two relatively new buildings situated on the harbor in Sevastopol. As with the other former Soviet institutes in our experience, this one looks much older than its years as the result of shoddy construction and general lack of maintenance. As mentioned previously, in addition to the main center in Sevastopol, there is the Branch at Katseveli, which is discussed in more detail in the following paragraphs; an Acoustic Institute in Odessa; the Technical Design Bureau in Sevastopol; and the Guinea Research Center in Guinea, Africa.

The Institute operates five research vessels, the *Akademik Verdnadsky* (5560 tons, 120 m long, built 1968), the *Mikhail Lomonosov* (3950 tons, 102 m long, built 1957), the *Professor Kolesnikov* (1000 tons, 64 m long, built 1962), and the smaller *Trepang* and *Ustritsa*. These are capable ships, with the usual range of oceanographic facilities such as winches, laboratories, and scientist staterooms. The *Vernadsky* is a very large research vessel, with 20 laboratories with almost 600 square meters of floor space. It is designed for long expeditions with legs as long as 50 days, and has berths for almost 80 scientists and technicians. Unfortunately, it also has a crew of about 80 and a large appetite for fuel. We had the opportunity to tour and to live temporarily on both the *Vernadsky* and the *Kolesnikov*.

MHI is in the precarious position of not having the funds to continue operating these vessels, and they presently are used as passenger ships. We had the opportunity to cross the Black Sea on the *Vernadsky*, and we observed both the *Vernadsky* and *Kolesnikov* ferrying "businessmen" across the Black Sea with consumer goods bought in Istanbul

for sale in Russia. Turkish chocolate was the primary marketable product that we observed during our trip. Working the ships in this way at least provides some hard currency for the Institute and keeps the crews together. Long-range ship management decisions are being affected by this commercialization. A plan to replace a now-removed mainframe computer on the *Vernadsky* with a network of personal computers (PCs) for scientists is being weighed against installing a commercial restaurant for businessmen.

The MHI administrators have been attempting to "sell" time on the ships. In addition, numerous private companies have approached Western scientists looking for interest in buying ship time. The duplication is due to private joint-venture companies being set up to facilitate marketing and handling hard currency, but it does make us wonder who really represents them.

As an aside, the quoted prices for ship time seem unrealistically cheap (apparently due to subsidized fuel and crew), but it is hard for us to see how these ships can operate efficiently and compete with our research vessel fleet on this basis. Our experience is with smaller research vessels, and these large ships burn on the order of 20 tons fuel per day and have large crews in addition. With the present and known future shipboard sampling methods that are used in the West, only a few scientists and technicians could work these ships efficiently at one time. It is not clear what the others in the large complement would do in the meantime that is not done as well or better in the laboratory at home.

An additional problem of hiring these ships that is foreseen by Western science administrators is that they might undercut continued support of our own research fleet. Finally, there is great uncertainty in the availability, ownership, and actual operating costs in the future, and these uncertainties are unacceptable in our scientific planning system. Consequently, their quest for aid for these ships continues with only occasional success.

So what are they going to do with these large research vessels? We wonder if there is a way to use their longer range and duration, their greater space, and the larger scientific parties that they could support without jeopardizing our research plans and perhaps our own fleet. It is unfortunate that these newly available scientific resources are not being used, but if nothing changes in the near future, they eventually will be removed from the world inventory of scientific assets.

COMPUTERS AND COMMUNICATIONS

The real capability for state-of-the-art research in the ocean is not driven by the capability of the ships as much as by the other facilities that are available for sensing the ocean, for modeling it, and for analyzing the results in each case. Ultimately, this comes down to the analysis capability of the staff and the availability of modern instruments and computers to obtain good data and to perform the appropriate analyses quickly and accurately. The instruments that were available for us to see at MHI were uniformly and seriously behind the state of technology in the West. In addition, the computer capability is extremely thin. There are about 40 PC compatibles scattered about the laboratory spaces, most of them with 286-level processors, but disks and paper are so scarce as to be practically unavailable. Software is a combination of in-house development and commercial packages. We saw no color, or even adequate grey scale, plots of images and fields of data. Because of this, most scientific products, both graphical and textual, were significantly behind Western standards.

Finally, communications facilities for scientific interactions are extremely important in the West, and these are almost nonexistent at MHI. Communications are discussed in more detail in a following section.

KATSEVELI BRANCH

The Department of Complex Methods of Investigation, headed by Dr. Leonid Koveshnikov, is located at the Katseveli Branch. This branch is about 50 km away along the southern coast of Crimea, much nearer to Yalta than to Sevastopol. It has three main groups with a total of about 130, of which 80 are classified as scientists. The Department of Experimental Hydrophysics, headed by Dr. Vogoslavski, has 25 members and works mostly in the Black Sea. The Department of Complex Methods of Investigation or Hydrophysical

Fields is headed by Dr. Koveshnikov and has about 30 members. His group has manned the research vessels for most of the previous work in the Black Sea. The third department has almost 30 people and supports work on the research towers at Katseveli.

Katseveli was the original location of a hydrophysical station organized and manned in 1928 as a result of the efforts of Dr. Shuleikin of the Academy of Sciences. The coastline in the vicinity of Katseveli is very steep and rugged, with a narrow shelf. Its beauty has led to the construction of many group vacation properties along the coast. The station began measurements of water properties in 1929 and has done so continuously since then except for a gap during World War II. An offshore instrumentation mast was installed in 1969, and an offshore platform was installed in 1982. The latter is a multi-leg platform in 30 m of water about 600 m from shore. It is 20 × 20 m in size, with a floor 12 m above the water; it has 5 laboratories and 6 cabins to house 16 scientists. Water, electricity, and telephone are supplied by cable from shore. It has an environmental measurement system for air and water temperatures and velocities at several levels, but the sensors and recording equipment are ancient by our standards. It also has a telescopic mast that can be raised to 30 m height to mount instruments, and in the past this apparently has been used to mount a radar antenna.

This platform is of moderate interest because it is one of the few remaining oceanographic research towers in the world. These towers are expensive to maintain, as these scientists now are finding out, and Dr. Koleshnikov is looking for any support that might be available to keep it in operation. Unfortunately, unlike a research vessel, it cannot easily be moved to different locations, but is restricted to a single location along a very rough coastline. In addition, an unfinished, semi-submersible, deep-water platform is moored close to the shore facility. Dr. Korotaev, Deputy Director for International Relations, estimated that it could be completed on the Ukrainian economy for about $200K. It might be attractive for remote sensing validation work, but it has very large legs that obviously would obstruct both air and water motion past the platform, a problem that is widely recognized by marine meteorologists in the West.

Finally, there is a very large circular wind-wave tank at Katseveli that is unique in our experience. The diameters of the two walls are 36 and 40 m, and the total depth for air and water is 5.6 m. Multiple fans along the roof provide winds up to 19 m/s. It was built in 1953 and used until 1982, but now is inoperable and in disrepair. Apparently a considerable amount of research was performed in this facility, with many publications in the Russian literature. Dr. Koleshnikov would like to see it put into operation again, but we fail to see where it fits into today's research on air-sea interactions. In our view, the secondary flows in both air and water must be a dominating feature of the dynamics, perhaps interesting in their own right as a scientific curiosity, but quite unrepresentative of the ocean boundary layers.

ONGOING PROJECTS AT MHI

Professor Eremeev is a member of the Steering Committee of the Cooperative Marine Science Program for the Black Sea, and the Institute seems to be a contributing member to this international effort.[1] MHI also is a contributor to the Tropical Ocean Global Atmosphere (TOGA) Atlantic Panel and to the World Ocean Circulation Experiment (WOCE), but continuing support is uncertain because of the unavailability of funding for the ships. The ships were the primary contribution that MHI, as in fact all Russian institutes, were thought to bring to the international community when planning WOCE during the last decade, but now the situation clearly has changed.

GENERAL COMMENTS ON SCIENTIFIC INTERACTIONS

A group of U.S. oceanographers and national science policy makers met at the Woods Hole Oceanographic Institution in 1991 to discuss how scientific collaboration with the oceanographic institutes of the Confederation of Independent States (CIS) (referred to earlier here as FSU) might best be improved. The findings of this group were that in the near term the most effective method would be to establish one-to-one liaisons between individual scientists in the CIS and those in the West. This section on scientific interactions was produced with this model of individual interactions

in mind. We found great enthusiasm for communication with the West, an enthusiasm that possibly is fueled by a need for funding support to ensure the continuation of these oceanographic establishments. Unfortunately, we also found cultural, organizational, and infrastuctural impediments to the degree of communications necessary in normal Western scientific liaison between individuals.

The scientific staff of this institute appear to be very active, with a number of them trying to gain access to Western scientific literature and to publish their work in the West. Many scientists were present at the Institute to talk with us over a weekend and even during a holiday. We found that they were very much interested in speaking with us. Unfortunately, we are of the opinion that there are a number of fundamental reasons why this scientific research institute is having difficulty in working with Western institutes.

Several of the reasons are well known and have been discussed in the Western scientific literature as well as in the report of the Woods Hole meeting. First and foremost, they do not have adequate communications with scientists outside their institute. The fundamental reason for this is the terrible communications infrastructure in the FSU, and specifically, in Sevastopol. Heretofore, the only way to communicate was by telex, which is very limiting because it is too slow and indirect for normal scientific communications. MHI now has an OMNET terminal, thanks to arrangements initially made by the Woods Hole Oceanographic Institution, so the problem of connectivity has been overcome. Unfortunately, there is only a single OMNET terminal. It cannot possibly carry the large number of electronic mail exchanges that are normal between scientists in the West. We will return to this subject below because it relates to another fundamental problem.

A second problem is the difficulty of visiting Sevastopol. For the Western scientist, there really are no commercial facilities for sleeping and eating in the city. Institute administrators or scientists must attend to a visiting scientist's daily needs. We had to depend entirely on arrangements made specifically for us. Our accommodations changed daily and included a spartan hotel (no heat, hot water, or food), a scientist's spare room, and the research vessel *Kolesnikov*. In addition, Sevastopol remains a closed city, so special arrangements, including papers with many official signatures, have to be made to enter the city. Travel to Sevastopol is not simple. Air connections are only through Moscow, requiring an overnight stop there, both coming and going. In addition, the closest train and air terminals are at Simferopol, which is a two-hour drive from Sevastopol by automobile. Making the connection between Sevastopol and Simferopol was a nightmare for one U.S. oceanographer within the last year. Informal travel for visiting scientists such as is typical in the West simply is not possible at this time.

Another problem, and one that surprised us, is the long heritage of the scientists pursuing their research in a noncompetitive environment. Historically, scientific goals have been determined through a central planning structure, and the direction and support of research of the typical scientist has been provided from above. This has resulted in two related problems. One problem is the reduced level of productivity of some of the scientists and therefore of the Institute as a whole. This of course was difficult to assess directly, but it was expressed verbally as a frustration of department and laboratory heads on more than one occasion. This was also shown in the complacency in quoting work that was published in the Western literature some time ago (a typical lag being three or four years) rather than being concerned about what research is being done today or, better yet, being planned for next year.

A related problem is a pervasive attitude in which they pursue their research almost entirely independent of the work of scientists and institutes outside their own, often even independent of work in other institutes within their own country. For example, we saw almost no interaction between this institute and the equally large Institute for Biology of the Southern Seas that is immediately across the harbor in Sevastopol. Scientists and administrators do not know what their peers are doing, they do not know what each other's research vessels are doing or are even capable of, nor did they exhibit any interest when we queried them on this. They marveled when told of the University-National Oceanographic Laboratory System (UNOLS) research vessel scheduling system in the U.S.

The difference in the approach of scientific administration was highlighted by several conversations in which we attempted to explain to our hosts how the scientist is sponsored in the typical U.S. institution. They simply did not see any need for MHI scientists to communicate directly with others, nor the need for them to know the Institute's plans for the future. With no previous motivation for direct interactions of their scientists with others, administrators are now struggling with the necessity of communicating with potential sponsors outside their historical ones. As a specific example, their favored choice of arranging support for a new project is to engage in negotiations directly between the administrators of the Institute and the potential sponsor. Previously, they have seen no need for direct exchange between scientists, nor between sponsors and scientists, and now the administrators appear threatened by such exchanges.

This shows their basic lack of understanding of the structure of our scientific institutions—that has Principal Investigators essentially running small Research and Development businesses, having significant levels of planning, marketing including proposal writing, and financial accounting, with the institute providing only a sensible structure and community in which to work. It also displays a lack of appreciation of the need for technical exchanges and of current information on "who is doing what" in our highly competitive funding structure. This difference is so marked, it is no wonder we have failed to communicate well in the past.

Returning to the problem of inadequate communications capability, the single e-mail link at MHI is OMNET, the commercial electronic mail system that many oceanographers use, and this connection is centrally controlled. There is a single computer terminal, and all messages must go through a central point of control, which typically involves a hard copy for approval of the message to be sent. We have not had any difficulty getting a message to an individual scientist, but ONR is viewed as a potential source of funds and we doubt that normal scientific interactions would be as easy.

We perceived an additional problem that troubles us. The scientists and administrators have little idea of the workings of the proposal process or the importance that science sponsors in the U.S. place on the quality of proposals for future work. They are not aware of the high level of importance placed on the currency of information displayed in the proposal on the status of the science/technology and of national and international programs in the specific area of concern to the proposal. The tentative proposals for potential work that we have seen written by these scientists are far from acceptable to our funding agencies.

In the end, the chances of success of this institute entering the modern world of scientific research may well depend on the willingness and ability of its administrators and scientists to change their philosophical approach toward funding and administering their work. It seems to us that it is necessary that the individual scientist learn to interact one-on-one with their colleagues doing work of similar nature in the rest of the world. They must learn who these colleagues are, and they must communicate with them via modern means so that they can learn what they are doing today. Only then will these scientists be taken seriously as equal partners in Western scientists' plans for their future research.

One possible U.S. strategy might be to encourage our large research establishments to deal directly with the administrators of these establishments, to hire some portion of the assets of the entire organization to work on some large, possibly joint, endeavors that could be more easily accepted and implemented. This could maximize the utilization of the greatest assets in the CIS, which are: inexpensive, large, well-organized establishments of good scientists with large research fleets and laboratories in areas newly opened to the West. This would also foster appropriate individual interactions that would support the integration of CIS scientists and administrators into the Western scientific networks of communication and support.

CONCLUSIONS

The oceanographic research at this institute parallels similar research in the West, but it is several years behind in every instance that we examined. As expected, the instrumentation is significantly behind the state of the art, and the quality of the large data sets they publicize as being available must be considered to be suspect. The data sets are probably useful at some level in

areas like the Black Sea where the data available in the West is scarce. However, for most scientific purposes, they most likely are contaminated by biases in the instruments and therefore contain numerous erroneous data values. As to the scientific research, we found few instances of unique approaches or ideas that are not in practice in the West. The only unusual approach was the theoretical work in the Department of Wave Theory, and that approach simply is not supported in the West. In our view, it is far from an optimal way to advance the knowledge and understanding of waves in the ocean.

Returning to the original objective of this visit, we feel that we were able to construct an organizational diagram for MHI, and to identify specific scientists and the areas in which they are expert. We also were able to assess the work in a number of areas. However, the institute is so large and has such a broad range of ocean physics research and development work, that our limited expertise has enabled us to assess only a small fraction of the ongoing work.

In conclusion, we feel that the organizational structure of the institute is so different from those in the West, specifically in regard to the centralized control of the scientists and the direction of their work, that individual Western scientists will have a difficult time working directly with individual CIS scientists initially. We foresee a very long and tortuous path for individual attempts to form really useful collaborative working relations. In our competitive research system, the average scientist probably cannot afford to take the time to attempt to work with the scientists in this system, especially because of the high risk of failure of the liaison. This is exacerbated by our limited understanding of their present system of science administration and to what it might evolve. In the end, the integration of these scientists is a job for senior scientists and science managers in the West. The cost in time and resources will be very high, and in our opinion perhaps too high if such efforts are directed at individual scientists.

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Review of Physics Research at the P.P. Shirshov Institute of Oceanology—the Largest Oceanographic Institute in Russia

by J.P. Dugan

KEYWORDS: oceanography; air-sea interactions; remote sensing; instrumentation; acoustics

INTRODUCTION

The P.P. Shirshov Institute of Oceanology (IOAN) of the Russian Academy of Sciences is the leading broad-spectrum oceanographic research laboratory in the former Soviet Union (FSU). The science scene in Russia is changing rapidly as the result of changes in the government and its priorities, but the role of the Shirshov as the leading institution in its discipline has not changed to date. It remains the class institution of Russian oceanography.

The Shirshov Institute is located in Moscow and has branches in outlying regions. It has a broad range of facilities in the form of ships, laboratories, and instruments. Scientists here have many connections with oceanographers in the West, more so in total than in any of the other

Russian or Ukrainian oceanographic institutions that I have visited. This report provides a synopsis of the organization of the Institute, with specific points of contact, and a detailed review of the research in physics at the Institute for those laboratories I was able to visit.

The Institute was organized in 1946 with Academician P.P. Shirshov as its first director; it now is the largest oceanographic institution in the FSU. More than 1000 professionals are in Moscow, and another 1000 are in the combination of the Atlantic Branch at Kaliningrad and smaller ones in St. Petersburg, Murmansk, and Gelendzhik on the Black Sea. This second group of professionals includes the crews of the six research vessels and the submersibles operated by the Institute. Most of these facilities are operated from Kaliningrad by the director of that branch and the deputy director of IOAN, Dr. Vadim Paka. Dr. Paka is well known for his many years of work as a successful ocean engineer, specializing in instrumentation and related equipment. The Pacific Oceanological Institute in Vladivostok was formerly a branch of IOAN. It is now separate, although IOAN still operates the research vessel *Mendeleyev* in the Pacific.

IOAN is the only institute in the FSU that includes all oceanographic disciplines on the staff; all other institutes are specialized toward either fisheries or physics. The Institute has not previously worked in the Arctic because of the Arctic and Antarctic Research Institute's (AARI) long history of research there. However, they have now begun to work in the area because the ecological problems encountered require biologists and chemists, which AARI does not have on their staff.

This report reviews the research in ocean physics and related disciplines of ocean optics, remote sensing, acoustics, and instrumentation. It is timely; the Institute has been devastated because of financial abandonment by the present government in Russia, and its future is so uncertain that many scientists, engineers, and technicians are in the process of leaving.

OVERALL ORGANIZATION

The Institute is headed by Dr. Yastrabov, whose background is in deep-sea geological research using submersibles. He has been the director for almost five years, so it is time for the election of a new director. There are four main departments and several smaller ones. The Physical Department is headed by Dr. Rostislav V. Ozmidov, and it has more than 300 professionals. The Geological Department has two parts, the Geophysical and Geochemistry Departments, and has about 300 professionals. The Biology Department is headed by Dr. Vinogradov with about 150 professionals. The Technical Department has about 150 professionals, and with the administration and other personnel, the total person count in Moscow is about 1000. The phone book is the only organizational document that I was able to see. It was previously considered a sensitive document and was not available to outsiders. It is presently available for review, but I was not able to obtain a copy because of the lack of a copy machine. The following organizational structure was put together from notes on interviews with many individual scientists, laboratory, and department heads.

Physical Department

Doctor Ozmidov became the head of this department in April 1992. The department had previously been led for about two years by Dr. Voronovich who now heads an acoustics laboratory. Before that, it was led for many years by Dr. A.S. Monin, the very well known ocean turbulence expert. Doctor Monin simultaneously was the director of IOAN as well. This double hatting of heads of departments, laboratories, and groups is common throughout IOAN. The department has many laboratories:

Experimental Ocean Physics —
  Dr. Andrei Zatsepin
Space Oceanography —
  Dr. Vadim Pelevin
Theoretical —
  Prof. Georgy Barenblatt
Ocean Turbulence —
  Dr. Ozmidov
Hydrophysical/Hydrodynamics —
  Prof. Vladimir Kamenkovich, now at Lamont-Doherty Geological Observatory in the U.S.
Climate Modeling —
  Dr. "Dan" Seedov

Synoptical Processes —
Prof. Monin
Nonlinear Wave Processes —
Prof. Acad. Vladimir Zakharov
Ocean Optics —
Prof. Oleg Kopelevich
Acoustic Wave Propagation —
Dr. Voronovich
Noise and Sound Fluctuations —
Prof. Boris Kuryanov
Sound Scattering and Reflection —
Prof. Yury Zhitkovsky
Variability of Hydrophysical Fields —
Prof. Mikhail Koshlyakov.

Within the Physics Department, there are additional divisions of responsibility that require some explanation. There is a Department of Dynamics and Ocean Climate, which is headed by Prof. Yury Ivanov, and it has only the one laboratory named above, headed by Prof. Koshlyakov. There also was an Acoustics Department that previously was headed by the very well known Academician Brekhovskikh, but the laboratories do not now have a common focal point within the Physical Department.

Biology Department

The head of this department is Prof. Academician Vinogradov. He feels that his 150 professionals cover most of the field of oceanic biology, excepting the field of fisheries. They do not attempt to cover this because numerous other specialized institutes exist for this activity. The laboratories cover the surface to the bottom for all oceans and nearby seas. The laboratories are:

Functioning of Ecosystems —
his own laboratory
Oceanic Ichtyfauna
Plankton Ecology
Ecology of Mesopelagic Species
Ecology and Culture of Benthic Flora
Biochemistry and Hydrochemistry
Ecology and Mariculture of Microalgae
Bioacoustics —
mostly mammalian signals and communications
Geochemical
Microbiology of Black Sea —
Prof. Sarokin.

Geological Department

This department has the following laboratories:

Physical Geological Studies —
Corresponding Academician A. Lisitin
Paleo Ecology and Biostratigraphy —
Max Boroch
Theoretical Geodynamics —
Oleg Soroktin
Geomagnetic Studies —
Gorodnitsky
Paleo Geodynamics —
Lev Zonenschein
Geomorphology and Tectonics of Sea Floor —
Vladimir Kazmin
Structural Geology —
Sborchikov
Seismology —
Academician Sergey Soloviev
Geophysical Fields —
Vanjan
Oil and Gas Formation —
Corresponding Member of the Academy Geodihin
Oil and Gas Distribution —
Trutsuk
Geology of Mineral Resources —
Shelf —
Ibulatov
Ocean Chemistry —
Romankevich
Seismology of Core and Upper Mantle —
Neoprochnov
Geochemistry —
Volkov
Analytical Chemistry —
Rozonov.

Physical-Technical Department

This department is headed by Dr. Yastrabov and has the following laboratories:

Mathematical Programs —
programming support

Submarine Apparatus and Robots —
  Yastrabov's laboratory
Hydro-location of Ocean Floor —
  depth sounders
Telemetry
Measuring Techniques
Microprocessors
Bionics of Memory Systems
Exploitation of Deep Water Submarine
Apparatus —
  operators of MIR, PICES, etc.
  (large at 25 people)
Benthic Layer Optics —
  Dr. Vitaly Voitov
Hyperbar:^ Center —
  located on Lenin Prospekt
System Livability —
  also located on Lenin Prospekt
Scientific and Technical Information
Exploitation of Technology.

Applied Oceanology

The Department of Applied Oceanology is headed by Dr. Tinyankin who previously was a Soviet Navy admiral. This apparently was a closed department; it provided direct connection to Navy sponsors, and it is staffed mostly with administrators and previous high naval officers.

Atlantic Branch in Kaliningrad

The director of the Atlantic Branch is Dr. Vadim Paka, a well known ocean instrument designer. It has about 200 professionals plus another 200-300 including the crews of the research vessels. It is organized in three departments:

Experimental Geophysical Investigations —
  Dr. Paka
Geological —
  Dr. Emelianov Mickhilevich
Hydrology —
  Prof. Vitaly Bubnov
Science Fleet —
  Mr. Nikolai Meystrambo.

This branch operates the research fleet, and it includes the well-known research vessels *Akademik Vavilev, Ioffe, Kuznetsov, Keldysh, Shtokman*, and *Shelf*. The department also operates the research vessels *Strakhov* and *Petrov* of the Academy of Sciences Institute of Geochemistry, which is located in Moscow.

The following sections of this report provide detailed discussions on the research at IOAN, but I have attempted only to cover work in the Physical Department. This includes physical oceanography and closely related disciplines, namely ocean remote sensing, optics, acoustics, and instrumentation. The overall organization of the research is rather vague, and the activities and responsibilities of the various departments and laboratories overlap in many technical areas.

Ocean Turbulence Laboratory

This laboratory is headed by Dr. Rostislav Ozmidov, but he was not available during my visit. Doctor Iosif D. Lozovatsky provided a review of the research activities. He is a midcareer scientist who is exceptionally talented in conducting experiments and analyzing the resulting data to answer interesting scientific questions about small-scale turbulence and microstructure in the ocean. The general objective of his research has been to investigate mechanisms for the generation of turbulence, microstructure, and fine structure, and to establish their connections with larger scale processes. This research is important because these small scales ultimately dissipate the energy of the largest scale motions that break down into the mesoscale, and so on. He also has been involved in more applied work in which the objective was to understand how turbulence is created, how it evolves, and to establish statistics of levels of turbulence in the ocean. Specific dynamical processes he has studied include convection, double diffusion, and boundary layers. He provided a very good briefing on his past and present research.

Most interesting is his work on the double diffusion mechanism for generating ocean fine structure; he planned an experiment on this mechanism for fine and microstructure generation and evolution. This interesting experiment was carried out in February 1987 east of the island of Barbados, in a region where the diffusive mechanism is known to be dominant and is accessible to measurements from ships. Only after he had returned to his office after the cruise did he find out from

recently published journal articles about a very large U.S. research program on this subject. This program was called C-SALT, and it had supported a series of intensive observations in the same area two years earlier by a large number of investigators on several ships and aircraft. That he was entirely unaware of the U.S. program provides a sad but true measure of the lack of communications between Russian and Western oceanographers at the time. Nevertheless, his data and interpretations are very informative because they add to the previous information and they are from an entirely different perspective. During his observations, he had made long series of profiles of the fine structure "steps" with an underway profiler called Rybka that carries a CTD (conductivity-temperature-depth measuring instrument). The most surprising result is that two years after the previous U.S. observations, the values of temperature and salinity (T-S) that he observed in the layers were identical to those previously measured during the C-SALT observations. This cannot be an accident, and no one would believe that he had observed the identical layers, so he has concluded that these specific conditions are really a very stable product of the conditions imposed by the T-S characteristics of the water masses that drive the process.

Also, he concludes that the layers are dominated by vertical diffusion far from an apparent front at their lateral edge, but that intrusive effects are dominant in the vicinity of the front. In addition, he found that one 60-m high layer had convection cells that were 6 km long. These cells had amplitude larger than 0.01 °C, as opposed to cells of much smaller aspect ratio and amplitude found by G. Marmorino of the Naval Research Laboratory during C-SALT. The lateral size of the cells in Lozovatsky's case are close to the internal Rossby radius of deformation, so they could actually be eddies. Also, he found that the steps at the top and bottom of the layer have vertical deflections that are 10 percent of the height of the layer and are coherent with the locations of the cells. There must be some energetic dynamical process that provides the required potential energy to deflect these steps. Doctor Lozovatsky thinks the deflections are the result of internal waves on the steps and that the cells are driven by enhanced diffusion associated with the phase of the waves. On the other hand, it might be the other way around, with the cells driving the deflections of the steps. Either way, the observations and his interpretations are significant additions to the literature on the subject.

The publication reporting this result has an interesting history that I repeat here, as it is symptomatic of another problem. He wrote up the results, and I believe the manuscript he showed me is really quite good. It was submitted to the Russian journal *Oceanology*, which is a publication of the Academy of Sciences. To make a long story short, the paper was not accepted, but it has taken a long time to ascertain this; it is just now being rewritten in English for submission to a Western oceanographic journal. My brief scanning of this and another manuscript confirms that they are publishable in English journals, although they still could use some polishing. In the meantime, other manuscripts are being submitted to Western journals.

Continuing with the description of Dr. Lozovatsky's work, during several recent long cruises he has made measurements of turbulence in the marine boundary layers at the surface and bottom, across the Gulf Stream, in the wakes of seamounts and islands, and in intra-thermocline lenses. All of these have some interesting aspects associated with them. The island work was done while two U.S. scientists (Dr. Mark Baker of the Applied Physics Laboratory of The Johns Hopkins University and Dr. Carl Gibson of Scripps Institution of Oceanography) were aboard as observers on research vessel *Kurchatov* cruise 51 to make observations on the utility of the Shirshov's microstructure instrumentation and data. I believe they have reached tentative agreement that the data are up to Western standards, and a number of joint papers on the results are in review and/or in press.

Doctor Lozovatsky also has made interesting measurements of the structure of the benthic boundary layer on the continental shelf off West Sahara. These were made during research vessel *Keldysh* cruise 26 in December 1991 - January 1992. The ship occupied more than 90 density stations to provide an idea of the variability in the surface and benthic boundary layers. Profiles were made to the bottom with a combined Neil Brown CTD and nephelometer. Some of these stations also included a rosette sampler to obtain high-resolution vertical details of the chemistry in the benthic boundary layer. Current meter moorings

were then set, and three detailed drift sections were made while obtaining continuous profiles of the benthic boundary layer. The data exhibit very large variability in all properties; however, he feels there is sufficient correlated structure to make a coherent story about the dynamics of the boundary layer in this snapshot of data on this shelf/slope region of the ocean. This should be an interesting analysis in view of current Office of Naval Research (ONR) interests in shallow-water and sediment-transport processes.

Doctor Lozovatsky works with a number of interesting instruments. They are developed and deployed for him by Dr. Anatoly Nabatov of the Atlantic Branch in Kaliningrad. They include the Rybka, or fish, that is a Neil Brown CTD in a heavy towed body that is winched up and down as the ship proceeds underway. This provides a highly detailed cross section of the temperature, salinity, and density as a function of depth and distance along the tow direction. This instrument was used, for example, to collect the detailed data on the steps and layers in the C-SALT region. The instrument can be profiled as deep as 600 m and at tow speeds up to 6 knots, but probably not simultaneously. He also uses the Baklan free-fall microstructure profiler that has a micro-conductivity sensor, a temperature sensor, and a two-component airfoil-type velocity sensor (as commonly used by the U.S. and Canadian microstructure community). Finally, he also uses the towed microstructure system Grif that mounts the same sensors as above in a towed body for horizontal data on the microstructure. In this case, the body is the shape of a torpedo and, although there is fairing on the cable, there is too much vibration for useful velocity data on the microscale.

Doctor Anatoly Erofeev and Dr. Nikolay Korchagin are scientists in Dr. Lozovatsky's group, and they have been co-authors on his papers. Both seem to be quite solid scientists. Some of the papers they currently have in progress are co-authored with Dr. Carl Gibson of Scripps, who is helping with interpretation and translation.

As to the future, Dr. Lozovatsky expects to continue his interesting work, although it probably will be done at the State Oceanography Institute in Moscow where he is expected to move. His first favorite project is to produce a climatology of ocean turbulence by using limited direct measurements and a statistical correlation of the turbulence parameters determined in these measurements with larger scale environmental parameters. Also, he hopes to be able to compare the measurements of turbulence in the wakes of islands and seamounts with a model of their evolution and decay. Finally, he has constructed a model of the turbulence structure in the benthic boundary layer, and he hopes to compare the predictions with the observations off of West Sahara.

Experimental Ocean Physics Laboratory

Doctor Andrei Zatsepin is head of this laboratory, and he gave me a lengthy briefing on the work in three subgroups. The first group is headed by Dr. Shapiro; it has three professionals, and it studies intra-thermocline lenses and ocean fine structure. Doctor Shapiro has identified intra-thermocline lenses from data previously acquired by the Shirshov in the Indian Ocean. He has named them "Reddies" because of their origin in Red Sea water and their obvious similarity with the "Meddies" in the Mediterranean outflow water in the thermocline of the North Atlantic Ocean. He also has worked on data associated with the Meddies, and has a theory on the mechanism for their generation. In addition, he has constructed theoretical models of these lenses that include the effects of diffusion and the differential rotation, and has found that the former is the limiting factor in the lifetime of these features. Doctor Emelianov of his group briefed me on his work on fine structure in the Antarctic Polar Frontal Zone, where he is attempting to separate the effects of vertical mixing from isopycnal intrusions.

The second group in this laboratory is headed by Dr. Vlasov. It has four professionals and designs and constructs new hydrophysical instruments. Dr. Vlasov has a technique that he feels will enable simultaneous measurement by a profiler of depth, temperature, and salinity by measuring only the index of refraction of the water. The instrument uses three channels that apparently compensate by their geometry for the effects of these three parameters on the water density. Thus, he uses only the refraction of light to estimate all three. A preliminary version has been tested at sea, but there were technical difficulties apparently not associated with the technique. Although they

feel they are on the right track, no data are available to date to see whether it works as advertised. Additional testing was planned for October 1992. Bob Millard of the Woods Hole Oceanographic Institution is an expert in CTD measurements, and he apparently has agreed to do some joint work with them. Any progress in this area will be interesting because it is an entirely new way to measure these parameters at sea; the limited accuracy and resolution (sensitivity) of present methods for measuring temperature and salinity of sea water is continually being pushed by the requirements of state-of-the-art physical sciences.

The third group in this laboratory is headed by Dr. Zatsepin himself. The group has four professionals, and it constructs laboratory models of oceanic features in rotating and stratified water tanks. This work was begun by Academician Federov's personal interest in the fine structure and lateral intrusions that are noted in vertical profiles of temperature and salinity measured in the sea. These phenomena have been studied by using physical models in density stratified water in rotating tanks. They have studied lateral intrusions of neutrally buoyant water with and without temperature and salinity anomalies, lens models, and mixed region collapse models. They have two rotating tables of 1-m diameter, but these currently are not in use because of the lack of material resources.

Doctor Zatsepin had a student who was temporarily at the Institute but now works at the Atlantic Branch of the Shirshov in Kaliningrad. Doctor Andrey Krylov is performing experiments under the tutelage of Dr. Zatsepin on turbulent mixing in density stratified shear flows in a laboratory water tunnel. The purpose of the experiments is to understand mechanisms associated with fine structure in the vertical profiles of ocean temperature, salinity, and density. The tunnel is a design similar to one first used by Odell and Kovasznay in the Department of Mechanics at The Johns Hopkins University many years ago. It is a circular channel in which the water is density stratified by salt. This is allowed to diffuse over time until the water is continuously stratified. Then, a cylinder made up of interlaced disks is spun up to provide a controlled horizontal stress to the water in the tank. The speed of the flow can be increased until dynamic instabilities generate turbulence in the flow. The evolution of the state of the fluid is measured by a small profiling conductivity sensor that provides a sequence of density profiles. Only preliminary results are available to date, but the data that I saw exhibit an interesting, continually varying series of steps and layers of fine structure. The layers divide, merge, and grow as they eventually mix the fluid in the tank. The generation and evolution of these steps and layers is being studied. The laboratory has a Disa hot-film velocity probe that will be used to estimate the mean velocity profile and the level of turbulence in specific locations in the flow, but they have not yet attempted to make more continuous velocity measurements. Both a hydrogen wire and dye pellets are being examined for this purpose, and it will be interesting to see the results of the follow-on experiments they now are planning.

Doctor Zatsepin also works with Dr. Alexander Soloviev, who officially is in the Laboratory for Benthic Boundary Layer Optics in the Technical Department, and Dr. Soloviev briefed me on his present research. He has published some interesting results on the thermal micro-layer at the air-sea interface, and he is continuing this research. He is working on air-sea interaction issues related to the upcoming TOGA-COARE (Tropical Ocean/Global Atmosphere — Coupled Ocean-Atmosphere Response Experiment) observations in the Equatorial Pacific. He provided an especially interesting demonstration of instrumentation and data that he has obtained by using previously unavailable sensors. He works with a freely rising device (similar to but much larger than the WAZP [WAve Zone Profiler] developed at Oregon State University) to measure the small-scale temperature, electrical conductivity, and three-component velocity structure in the surface layer of the ocean. He and a colleague (more on the colleague later) made three of the devices specifically for Dr. Zatsepin. This device can also be mounted on the bow of a research vessel several meters below the waterline to obtain measurements of the horizontal structure of these same physical variables. Finally, he also works with an extremely small temperature sensor that he plunges through the ocean surface to measure the top 1 cm of the surface temperature boundary layer.

I am interested in the multi-parameter instrument package because all the sensors are very

different from those commonly used for similar purposes in the West. Therefore, they represent an excellent opportunity to make a comparative test to see if they are as good as the specifications claim them to be. Conductivity is measured by a four-conductor probe that resolves 1 cm at speeds up to 10 knots. I could not get a useful number on its sensitivity. It appears to be more rugged but probably more accurate and with much better spatial resolution than the standard cells developed over many years of work by both the Naval Research Laboratory (NRL) and The Johns Hopkins University/Applied Physics Laboratory (JHU-APL). I have previously published a comparison of 5 cells that have been commonly used in the West, but this cell has the appearance of being better than any of them.

The velocity probe is a three-component electromagnetic current meter that resolves 1-cm scales at 10 knots or more, and the sensitivity is claimed to be better than 1 mm/s. It appears to be a much more rugged and sophisticated design than the airfoil microstructure probes commonly used in the West. Apparently, the specific one he showed me is only one of a series that have been built and tested. Finally, the thermal sensor is a resistance technique that is a long thin copper wire wound around a very thin laser-trimmed encapsulating cylinder This technique has been previously published, but I had not seen its specific mechanical structure before. It is claimed to have a frequency response of 20 Hz, which sounds a bit optimistic to me, but if it is true and it has good sensitivity, it also represents very good performance.

These sensors should be subjected to a comparison test. They apparently are available from Dr. Soloviev or his engineering colleague, Dr. Anatoly Arzhanikov, who works at the Central Institute Granit in Saint Petersburg. He is said to have an excellent turbulent-flow water tunnel facility for calibrating and measuring the dynamic response of these probes (however, scientists at the Shirshov feel that this Institute presently has even more severe financial problems than they do).

Doctor Soloviev showed examples of data from all three sensors in both the horizontal and vertical configuration that he had obtained on a recent cruise of the research vessel *Akademik Ioffe*. The data looked reasonable, but they also should be subjected to much closer scrutiny, especially the noise levels.

Finally, Dr. Grigory Suturin in Dr. Zatsepin's laboratory briefed me on theoretical work on the effects of diffusion of vorticity in intra-thermocline lenses and their effects on spin down of the eddy. There is a surprising result in that, for a time, the center actually spins up because of conservation of angular momentum before the whole eddy actually spins down. He has a paper in press for the *Journal of Marine Systems*.

In summary, the research in Dr. Zatsepin's laboratory continues, but at a much reduced level compared with previous years. The best experimental work is in conjunction with Drs. Krylov and Soloviev, neither of whom really work directly for this laboratory. The decrease in activity is due to their lack of funds to purchase equipment with which to continue their experiments. Unfortunately, when Dr. Federov died several years ago the laboratory lost the influence that they had for getting anything done for them in the Institute.

Laboratory for Variability of Hydrophysical Fields

Doctor Mikhail N. Koshlyakov is the head of this laboratory. He is well known for his observational and interpretive work in the many Russian POLYGON experiments where many moorings and density stations are occupied for durations of several months to study the dynamics of the mesoscale variations. The work entails the theoretical and experimental study of large-scale ocean currents, eddies, fronts, and water masses. This work started well before the joint U.S./U.S.S.R. POLYGON experiment, which was a focus of attention of theoretical and observational physical oceanographers in the U.S. in the late 1970s and early 1980s. He also was a principal player in the MEGAPOLYGON experiment carried out by 10 Russian research vessels in the NW Pacific in 1987, and they are just finishing their processing of the data. He is a co-author with Monin and Kamenkovich of a very well known book in English on the subject of synoptic eddies in the ocean. He now is occupied largely by work associated with the World Ocean Circulation Experiment (WOCE), as a member of the WOCE Scientific

Group and Core Project 2 (Southern Ocean) Working Group.

Doctor Koshlyakov is well known in the West. He was able to obtain $150K of U.S. funding in the last year to help support the research vessel *Akademik Ioffe* in the Southern Ocean to occupy WOCE section S4. This cruise had 15 U.S. scientists on the ship to make joint observations around the Pacific sector of the Southern Ocean at 65°S. The instruments were largely U.S. made, and Jim Richman of Oregon State University (OSU) was co-chief scientist. The U.S. has been asked to fully finance follow-on sections P14 and P15 in the SW Pacific sector, but he acknowledges that this is a very high cost and is unlikely to be supported. This causes a problem for the whole WOCE program because a number of sections will not be occupied if the Russians cannot live up to their prior commitments of ship time. There has been much criticism of the quality of Russian oceanographic data in past years, and the apparent purpose of the U.S. contingent on this cruise was to ensure the quality of the data collected.

Doctor Nikolay A. Maksimenko of this Laboratory works with surface drifters in the WOCE Drifters Program. He also has analyzed the problem of contamination of current meter measurements by motion of the mooring buoy (a problem that was recognized by U.S. and U.K. oceanographers and caused them to go to expensive subsurface buoys on their moorings way back in the 1970s). For the WOCE drifters, he has obtained a local contractor for construction of the buoy hulls, and he sends completed hulls to the Scripps Institution of Oceanography where the sensors and ARGOS satellite transmitter are added before deployment. The first lot of 48 is there now for testing, and it will be interesting to see how this collaboration works out.

Doctor Maxim I. Yaremchuk of this Laboratory has designed and constructed a numerical model that assimilates field data in a dynamical analysis that optimally solves the quasi-geostrophic equations. A preliminary version of this has been published in the *Ocean Modelling Newsletter* that is assembled at Oxford University (Peter Kilworth is contact there) under ONR funding (Alan Brandt is contact there), and it has been installed on a computer at Bedford Institute of Oceanography (Allen Clark is contact there). This is an eddy-resolving model that permits the assimilation of oceanic density and velocity data, and it provides a dynamically consistent solution. This is a subject of very active interest in oceanography in the West, and they claim that this is a unique approach to the problem.

Theoretical Oceanography Laboratory

Doctor Grigory Barenblatt is the head of this Laboratory. He was appointed head of a Theoretical Department with several laboratories by Dr. Monin when he first became the director of the Shirshov many years ago, to "beef up" the theoretical and modeling capability of the Institute. He is very well known in the West, and speaks well of many contacts there. He is leaving to take up the G.I. Taylor chair at the University of Cambridge, which is a two-year appointment. This Laboratory has a number of very good scientists, but many of them either have left or are scrambling to find positions in the West. In addition, others spend as much time as possible visiting Western institutions. Doctor Shrira, for instance, is known to be very capable in theoretical analyses of nonlinear problems, and he spends most of his time going to scientific meetings and visiting institutes in the West.

Doctor Barenblatt is a senior Russian scientist, and he spoke at length about U.S. and Russian problems in the support of science. He also briefed me on several problems that he is working on at present. He has analyzed the benthic boundary layer situation that was studied in the U.S. HEBBLE project. He found that the density of the particulates in the layer have a significant effect on the dynamics of the flow when the bottom slope is negligible but there is significant shear flow. He has shown that a small jet is to be expected in the upper part of the boundary layer because of the decrease in turbulent energy there. This effect is similar to one sometimes observed in the atmospheric surface boundary layer. He claimed that this has been observed in benthic boundary layer current meter observations, but Dr. Lozovatsky was involved in those measurements, and he is not so sure.

He also has an interesting analysis of a mechanism for the formation of fine structure layers and steps in the ocean temperature and salinity profiles.

This is a new idea, and although it has some questionable assumptions about the turbulence levels and distribution of turbulence in the ocean, he derives a new model equation (third-order differential equation), and has solved it for specific situations. It deserves attention as a potential explanation for a phenomenon that is well known, that has been analyzed by many scientists in the past, but has not been fully explained to date. I was somewhat surprised to find that he was not interested in talking about the validity of the assumptions in his model and that he is far removed from having some reasonably good grasp of the observational knowledge of the ocean that exists both within his own Institute and outside of it.

Dr. Barenblatt has a number of other active research topics of interest in physical and geophysical oceanography. It is interesting but not untypical of senior members of the Russian scientific community that he was mostly interested in talking about his individual research and not that of the scientists in his Laboratory. I was able to interview Dr. S.I. Voropayev of his Laboratory, for instance, only because he sought me out. He is a senior scientist, and he provided a very good scientific briefing on his work on "mushroom" vortices in density stratified fluids. As noted later, these features were first discovered in the ocean by scientists at the Shirshov, and they are of much interest to oceanographers in the West. This work is excellent, and a long series of articles has been published in Western as well as Russian journals (with what appears to be more than minimal overlap, unfortunately). The articles generally are quite well written compared with most of the Russian literature with which I am familiar. However, he is unaware of current work on this interesting subject in the U.S., although he knows of the appropriate scientists.

Department for Remote Sensing of the Ocean

Doctor Vadim Pelevin is chief of the Department of Remote Sensing. This department has one laboratory of the same name that is headed by himself, and a second laboratory (discussed previously) headed by Dr. Zatsepin. He had Dr. Sergey V. Semovski help him brief me on the work in the Remote Sensing Laboratory. A major part of it was a recent remote sensing experiment on the shelf and slope in the New York Bight. He provided a brief outline of the many sensors that they had on the ship. I was especially interested in scanning radars that were installed on the research vessel by the Institute of Applied Physics (of Nizhny Novgorod), as they were new to me, but he had no details on these sensors. They also had a towed profiling CTD fish (mentioned previously) that has been developed by Dr. Paka of the Atlantic Branch in Kaliningrad.

The second subject discussed by Drs. Pelevin and Semovski is a laser beam technique for measuring the distribution of chlorophyll, yellow substance (dissolved organic matter), and pollution in near surface water. It is mounted above the surface on the ship, and the scattered light is divided into seven frequencies to estimate environmental parameters by inverting a correlation matrix developed from previously analyzed remotely sensed and in situ data. This is interesting and, although I believe it difficult to do in any general sense (i.e., different water masses), they had a number of examples that they showed me. The work should be reviewed by a scientist more competent than myself in this area. They also have research associated with spaceborne multi-spectral scanners (their own on Cosmos 1390 with four channels called RESOURSE and the future U.S. SeaWiFS sensor that will have eight channels). They have not worked with U.S. Coastal Zone Color Scanner data to date, and I believe the lack of experience with this data and the associated scientific community will limit their impact on the rest of the science in the world. Again, they intend to invert the multi-spectral data to obtain the concentration of chlorophyll, yellow substance, and suspended matter.

Doctor Anna Ginsburg is a senior researcher in the Laboratory of Space Oceanology, and has recently returned from the experiment in the New York Bight on the research vessel *Akademik Ioffe*, one of the largest and newest of the Shirshov research vessels. The purpose of that experiment was to remotely sense the surface effects of large internal waves generated by tidal flows over bathymetric features. Research platforms included the *Ioffe* from the Shirshov, the Russian Almaz satellite with its synthetic aperture radar (SAR), the European ERS-1 (ERS-1 is the name of a U.S. satellite) SAR, a Russian aircraft SAR from the Space

Oceanography Institute (Dr. Etkin), and the U.S. Navy P-3 SAR. Doctor John Apel of The Johns Hopkins University Applied Physics Laboratory was an observer on the *Ioffe* with a number of other U.S. scientists and assistants. The several Shirshov scientists whom I spoke to about the experiment were not clear on how the experiment was organized and sold in the U.S. However, it must have provided a unique opportunity to assess the capability of these Russian platforms. I am most impressed that this was accomplished as planned. The project apparently provided financial support for the ship, but it was not clear to me whether it included support of the Russian scientists. In turn, apparently, the *Ioffe* lost an expensive CTD (by winch operator error) in shallow water, and these scientists were impressed that a U.S. underwater search group was located and transported quickly to the ship, and they located and recovered the instrument.

Doctor Ginsburg was the wife of the very well known and respected scientist and former head of the Physical Department, Dr. Fedorov, who died in 1988. Her expertise is analyses and interpretation of oceanographic data, especially the interpretation of remotely sensed images of the ocean. She claimed to have discovered mushroom vortices in the ocean in 1983 in conjunction with Dr. Fedorov. This subject as well as other aspects of the near-surface layer of the ocean is covered in her book with Fedorov, *The Near-Surface Layer of the Ocean*, which was published in English in 1988. The original discovery is interesting because it was observed from a photograph taken of unconsolidated ice in the Arctic. The ice acted as a tracer for the motions of the water associated with the mushroom vortex, and in retrospect, the feature is obvious in this and many later images of the ocean surface from space. This is only one of the many examples of features that were not known to exist in geophysical flows until discovered from remotely sensed images. These oceanic features presently are a subject of much interest in both countries (although communication between the appropriate scientists continue to be minimal). At present, it seems that the vortices are the inevitable consequence of any localized momentum impulse acting on the surface layer of the ocean. In addition, she has continued to investigate the surface manifestations of internal waves in the ocean thermocline, as in the experiment noted previously, and also vortex motions associated with islands in currents, upwelling fronts, and marginal ice zones.

Doctor Ginsburg gave me a short briefing on the work of Dr. Alexander Kazmin who was not present. He also has worked for about 15 years on interpreting images of ocean features observed from satellites and aircraft. He has worked with photographic and infrared data from Salyut and Meteor (among other satellites) on interpreting surface slicks, frontal zone features with his coined word "stairs", which are small minifronts associated with larger ones, long waves on current systems, eddies, upwelling, and surface effects of internal waves and "suloy", or current rips.

Laboratory of Ocean Optics

Doctor Oleg Kopelevich is the head of this laboratory as well as the Department of Hydro-Optics in the Physical Department. This laboratory is very big at 35 professionals. This is in addition to the Laboratory of Hydro-Optics in the Southern Branch of the Shirshov located at Gelenzhik on the Black Sea (headed by Dr. Nikoloyev), and the small laboratory in the Shirshov in Moscow headed by Dr. Voitov and containing Dr. Karabashev, the fluorescence expert. There also is a Laboratory for Benthic Boundary Layer Optics in the Technical Department, as noted previously, and headed by the director, Dr. Yastrabov. Finally, there is a Laboratory for Atmospheric Optics Over the Ocean in the St. Petersburg Branch of the Shirshov. Professor Shifrin was the head of this laboratory but he now is in the U.S. and it now is headed by Dr. Levin. This is a confusing mess of laboratories, and somebody might find it a worthwhile task to figure them out.

Doctor Kopelevich has numerous optics instruments that have been developed in his laboratory that are used for scientific measurements. They have profilers for light attenuation, transparency, fluorescence, scattering, etc. They presently are preparing for a joint hydro-optical and hydro-physical cruise in the Black Sea on the research vessel *Vityaz*. It is based at Novorrsijk near the Southern Department at Gelenzhik.

He has developed a plan for a further experiment that he says has been reviewed by Naval Command, Control and Ocean Surveillance Center

[formerly the Naval Ocean Systems Center (NOSC)] personnel for a passive/active remote sensing experiment, also to be performed in the Black Sea using the *Vityaz*. The goals of that experiment are very interesting, and I repeat them below:

- Evaluate algorithms and models relating upwelling spectral radiance to subsurface optical properties,
- Determine the potential of lidar and passive multi-spectral systems to detect natural internal waves, and
- Compare lidar and passive multi-spectral systems capability to determine bottom depth and composition.

All these objectives appear to be of some interest to the Office of Naval Research. The lidar is especially interesting; it has polarization capability to determine scattering characteristics and it can be mounted on a helicopter. It is green, with 532-nm wavelength. It apparently has been tested previously, and they feel they can determine bottom relief in very clear water to depths of 70-100 m, a number so large that it surprises me. The lidar expert in his group is Dr. Yuri Joldin.

Doctor Kopelevich has visited NOSC and has described his optics programs to Dr. Rod Buntzen. He also has briefed Dr. Gary Gilbert of NOSC who currently is at ONR. He was looking for support from NOSC for the above experiment, but has been told they have no money to do this. Finally, he has briefed Dr. Greg Mitchell of the SeaWHiFs program at National Aeronautics and Space Administration (NASA) in hopes of getting NASA support.

Doctor Sergey Sviridov of the Optics Laboratory summarized, both orally and in writing, their optical remote sensing wave measurement system on the research vessels *Akademik Ioffe* and *Vavilov*. They call it their Wave Registration System, or DSV (Russian acronym using first letters of the words in their language). This system has a scanning lidar that is emitted from near the top of the forward mast of the ships. It has a motion-compensation system to remove ship motion from the measured distance from the mast to the water. Neither explanation was particularly clear, but they would like to manufacture and sell units to interested potential users as a combined effort of Sviridov and others in the Laboratory along with the Finnish firm of Hollmin Electronics Ltd in Rauma. They showed me some time series data obtained with this instrument, but no spectra or comparisons with an independent control for estimating the accuracy. Amplitude resolution was claimed to be 10 cm. Any accurate method for measuring the wave spectrum remotely from a ship is worth pursuing; many applied projects do without this measurement simply because wave-rider buoys are difficult to launch, operate, and retrieve, and more often than not they require a specialist to interpret the data. However, I would like to see measured spectra and a comparison with a wave-rider buoy before further inquiries are pursued.

Doctor Genrikh S. Karabashev was recently in the Laboratory of Hydro-Optics in Saint Petersburg, but now is in this laboratory. Doctor Karabashev makes observations of vertical profiles of fluorescence, scattering, and transparency with in situ sensors to estimate dissolved organic matter, suspended matter, phytoplankton, and pollution, although it is not clear what he means by "pollution". He has written a monograph called *Fluorescence in the Ocean*, which was published in Russian in 1987. He admits that it is not up to date. He has made measurements with a new device developed in the laboratory to simultaneously measure profiles of temperature, chlorophyll, dissolved organic matter (yellow substance), and light scattering. Chlorophyll is measured by illuminating the water in a band of 400-460 nm and measuring fluorescence at 685 nm, while yellow substance is measured by illuminating between 350-390 nm and receiving in the 430-500 band. First results were made in 1984, and he feels this was unique at that time. Progress in the instrumentation has been evolutionary since then. He doesn't know about the present status of instrumentation in the West, but I doubt if it is unique in the West today. He also claimed to have discovered an intermediate depth maximum of the phytoplankton below the euphotic zone in the Baltic and the Skaggerak during observational work in recent years. He has many papers in Russian, some of which have been translated in the Soviet journal *Oceanology*.

Laboratory of Sound Scattering and Reflection

This laboratory is headed by Dr. Yury Zhitkovskii. This group performs research on acoustic scattering from the ocean bottom, the surface, and biological scattering layers and inhomogeneities in the interior. Vladimir Mozgovoy gave me a short briefing on his work on deep scattering layers using a profiler that illuminates the nearby water at 4, 5, 8, 10, 12, and 16 kHz. Also, he has one that has broad bands of 4-20 kHz and 20-50 kHz. They analyze data with biologists who make simultaneous biological trawls to determine the species responsible for the scattering. He has made these measurements in all oceans on many cruises. He showed me many plots of the spectral content of the scattering versus depth, but the only common thing in them is their high variability and the highly nonsystematic nature of the frequency spectra, in the sense that they very often exhibit significant bumps and valleys.

Alexander Nosov of the same laboratory spoke on scattering from the rough ocean surface, both wideband backscatter in the 2-50 kHz band and forward scattering in the 2-20 kHz band. The transmitter is suspended on cable from the research vessel and the receiver from a buoy some distance away. Also, the receiver sometimes is suspended from a sailboat that is available on the *Ioffe* and *Vavilov*, their two acoustic research vessels. He is familiar v ith both rough surface and bubble scattering mechanisms but expressed no awareness of the present research in this area in the West. He also spoke on scattering from the bottom and sub-bottom in the 27-450 Hz frequency band. They use specially encoded 4-second pulses by using a 12-ton transmitter suspended from the *Ioffe*. They assume that most of the scattering from the bottom is vertical and have performed an experiment using the source, its mirror image from the surface, and coherent processing to prove this case. He also told me of work using a towed array of hydrophones; it has 33 phones but it apparently is only tuned for 5 kHz.

Alexander Fokin of the same laboratory showed me bottom scattering research in which they are attempting to identify both the mechanism for scattering and the geological structure of the sub-bottom. They suspend a transmitter that has several narrow bands from 2 to 16 kHz and a camera to document the visual structure of the bottom. They have no directivity, and they separate sub-bottom reflections from the smaller grazing-angle bottom surface reflections by varying the height of the source above the bottom and comparing the results. They have interesting results of comparisons of the acoustic bottom structure and sediment cores, although their present coring technology apparently limits this to very shallow depths of core. He also showed me some echo sounder data that were obtained with the Finnish multibeam system that is installed on the *Ioffe*, but it doesn't appear unique in any way.

Doctor V. Kuznetsov of the same laboratory talked about parametric sonars in their research and also his research on scattering from ocean inhomogeneities. He apparently was a graduate student of Academician Hohlov who, he said, is the father of the parametric sonar in Russia. Their system has operating frequencies around 33 kHz, with the difference frequency between 2 and 5 kHz. The resulting resolution is 2 m in the vertical and a beamwidth of 2 degrees. He had interesting data on profiles, including hydrothermal plumes obtained near the bottom near the Mid-Atlantic Ridge. He also is interested in scattering from thermal inhomogeneities in the water column. This was interesting, but the theory is incomplete in comparison with that of Louis Goodman at the Naval Underwater Systems Center in Newport, RI, recently, and he had only Neil Brown CTD data for his estimates of the in situ temperature microstructure. His understanding of the ocean microstructure on the appropriate scales is weak. His acoustic band is 10-30 kHz. Most of what I saw has been published in *Soviet Physics - Acoustics*, which is translated.

Tengiz Kharatishwili of the same laboratory briefed me on a multi-beam scattering recorder (called MUSCAT) that they have designed and built in-house. It is an active device that has both transmitter and receiver on a towed underwater vehicle, and I obtained brief documentation on this. The two transducers are orthogonally placed on the vehicle, and the signals are digitally synthesized so that both the outgoing and incoming beams can be steered. They have interesting results on an experiment where the bottom exhibits two reasonably discernible scattering layers, and they analyze the

data in such a way as to determine both the distance between the scattering layers and the average sound speed in the zone between them.

Laboratory of Acoustic Noise and Sound Fluctuations

Doctor Boris Kuryanov is head of this laboratory. The interest here is the generation and propagation of low-frequency noise in the ocean, particularly the 5-100 Hz frequency band. This is dictated both by interest of the former Soviet Navy and also by the fact that sound propagates to long distances in this band. The major sources are shipping and dynamic processes at the ocean surface, and the principal issue is how best to separate the two.

He claims that the laboratory has the best instrumentation development capability in the Institute. They have designed and constructed seven automatic acoustic recording systems. They can be moored on the bottom or freely floating at depth. In each case, they have a short vertical array of 16-element hydrophones up to 200 m in length, and I obtained a specification sheet in English on these. They were designed and constructed in their laboratory, including the computer, acoustic recorder, and mechanical components, even including the acoustic releases. They originally recorded the raw analog signals on recorders they built around Teac 14-channel read/write heads, but now data are recorded after beamforming to reduce the total volume. They have recovered these capsules without a single loss in more than 300 deployments during experiments; this is a remarkable record.

The design of the floating capsules is interesting because they have a microprocessor control system that can be programmed (or externally acoustically commanded) to maintain constant depth and then move to other depths in any sequence. The depth is maintained by controlled pumping of two fluids of different densities from storage bladders. They would like to construct and sell these capsules, and they have formed a small company to do this. Without the acoustic components, they estimate a price of $3K per floating buoy. This includes a titanium hull that I find amazingly thin for full-depth operation. They have interesting results from deployments of the array near the bottom. They have a method of determining the sub-bottom acoustic properties of the sediments by a method they call "bottom tomography". This is a processing technique whereby they utilize the interference pattern of a directly arriving wave and the wave that arrives after being refracted in the bottom. He claims that this is a unique method, but he is not well read on recent Western literature, and the validity of the claim of uniqueness is unknown to me. They also have numerous results for the vertical directivity of arrivals of ambient signals and how the directivity pattern changes with depth throughout the water column. Apparently, they have published none of this in English.

They have difficulty affording their acoustic research vessels, so they have outfitted a sailing vessel. Some of their scientists have just returned from a sea test with a 16-element towed array, apparently the first towed array with which they have worked. He has a proposal for a tomography experiment over a 200-km range, but typically it lacks sufficient detail to see what the value really is.

They also have a portable acoustic positioning system that they would like to market. It is somewhat different from those I am familiar with in that the baseline is planned to be 20-25 km, whereas the deep-sea ones I know about have a baseline only approximately equal to the water depth, 6-8 km or thereabouts. It relies on direct-path transmissions, as do those in the West, but the baseline is limited only by the extent of the (refracted) direct path. The pulses are coded as long pseudorandom signals, and the arrival times and doppler at the several receivers are calculated and encoded and sent on to a tending ship. The clocks of the different receivers are synchronized as necessary by a special survey procedure of the tending ship so that transponders are not necessary for this system. It would be an inexpensive system (approximately $10K) if it were reliable and they could market it.

Acoustic Wave Propagation Laboratory

This laboratory is headed by Dr. A.G. Voronovich, who was away during my visit, so Drs. Yu. A. Chepurin, and V.V. Goncharov briefed me on the research being conducted. They

have been studying acoustic propagation through the ocean with horizontal as well as vertical variability, and are pursuing a methodology of "tomography" to determine the two-dimensional sound speed structure between a sound source and a receiving vertical array. The methodology was said to be able to include the effects of bottom variability over the range between source and receiver. The method is based on an extension of simulations using orthogonal eigenfunction principles that they have previously published. They have specific results for an experiment with a 560-m-long vertical array. This array contained 29 hydrophones with 20-m equal spacing and was deployed in the Norwegian Sea from the *Vavilov*. The *Ioffe* transmitted a 105 Hz continuous wave source about 50 and then 100 km distant. By using the vertical sound speed profiles at the locations of the ships and three points in between, matched field and matched mode processing was used to determine the sound speed field everywhere along the propagation path. This was done by minimizing the difference of changes in assumed profiles on the theoretical and the experimental received acoustic field. The result is described in a manuscript that has been submitted for publication in the *Journal of the Acoustical Society of America*, and I have a copy of it.

ATLANTIC BRANCH AT KALININGRAD

Dr. Krylov provided me information on the Atlantic Branch in Kaliningrad. The director is Dr. Vadim Paka, as mentioned previously. It has about 200 professionals plus another 200-300 employees, including the crews of the research vessels. It is organized in three departments. The Department of Experimental Geophysical Investigations is headed by Dr. Paka himself. It has small groups associated with specific instruments or projects. Doctor Valery Nabatov leads a group that develops the Baklan freefall microstructure profilers that appear to be better than any other microstructure or turbulence instruments I have previously seen at any of the FSU institutes. These instruments have been the subject of attention by scientists at Scripps Institution of Oceanography (Dr. Carl Gibson) and at the Applied Physics Laboratory of The Johns Hopkins University (Dr. Mark Baker). Since they have analyzed data from at-sea experiments to assess their quality, I will not dwell on them.

Doctor Nikolai Golenko leads a small group that works with a towed CTD capability called "fish" or, in Russian, "Rybka". This is of some interest; Western scientists are presently trying to upgrade their towed profiling capability beyond that which is commercially available. This development actually is crude, but apparently very rugged and reliable. They use a heavy streamlined weight with a Neil Brown CTD, and it is profiled by constant use of the winch. The up and down speed is somewhat greater than 1 m/s, so they can achieve high horizontal resolution at slow underway speeds. Doctor Krylov leads a small group engaged in laboratory experiments reviewed previously.

An additional group in this department is an instrument calibration center headed by Mrs. Tamara Artemeyeva. Doctor Krylov admits that instrument calibrations were very bad a decade ago, but he feels that the purchase of Neil Brown CTDs and construction and instrumentation of this calibration laboratory have solved this problem, and the data now are up to international standards. Interested parties might consult Bob Millard of WHOI on this issue, as he perhaps has fairly recent information on their calibration reliability. A final group in this department, headed by Dr. Boris Chubarenko, specializes in ecology and numerical circulation modeling.

Also at the Atlantic Branch, a Geological Department is headed by Dr. Emelianov Mickhilevich, a Department of Hydrology is headed by Professor Vitaly Bubnov, and a Department of Science Fleet is headed by Mr. Nikolai Meystrambo. The fleet includes the well-known research vessels *Akademik Vavilev, Ioffe, Kuznetsov, Keldysh, Shtokman,* and *Shelf*. The Department also operates the research vessels *Strakhov* and *Petrov* of the Academy of Sciences Institute of Geochemistry that is located in Moscow.

Doctor Krylov says that he, Dr. Paka, and Dr. Chubarenko are attempting to attract funding from the local city government of Kaliningrad to address the many issues associated with the ecology of the harbor and estuary.

FACILITIES

The research vessels discussed just above have been used often enough now in the West that there is little need to go into their capabilities. The *Vavilov* currently is on long-term charter to a German firm and is, therefore, available only once or twice over the next five years. The others currently are available, but they will not be for long, since they are a potential source of hard currency just as with the *Vavilov*.

The facilities in the institute are not up to Western standards. There is no local area network for communications, and there are only a small number of computers that mostly were obtained more than a year ago. There are no funds for normal maintenance, so instruments and laboratory facilities are in disrepair. The tanks in Dr. Zatsepin's laboratory, for instance, are not operable. Finally, simple resources such as light bulbs, papers, and disks are not available. The software that is in normal use is prehistoric; no reasonable 2-D graphical capabilities exist and even word processing is difficult. Normal support software that is readily available in the West practically is nonexistent.

This difficulty with computers also hampers scientific communications both within and outside the institute. For example, there is only one telemail connection (on OMNET) that has connections with the West, and access to it is jealously guarded. This lack of access is due to several problems. First, there would be very heavy usage (and cost) if everyone could use it. Also, as mentioned above, there is no local area network and little paper and disks available to transfer the messages around the institute. Finally, there is an apparent lingering penchant for the administration to keep the scientists in the dark as to communications with their peers or sponsors outside the institute.

This last problem will be solved only with the advent of alternative communication channels, or ready access to those that presently exist. There are several e-mail boxes now available in the institute, and it will be interesting to see how these fare in the near future.

FINAL COMMENTS

What is the future of this Institute? Well, the story from the Academy is that they will struggle on. However, the evidence from actually being there is that only 20 or 25 percent of the personnel actually show up for work. Those who are able are obtaining hard currency elsewhere either in the local economy or, if possible, by traveling to the West. Salaries are still paid to all former employees, but these salaries are not worth much in light of the recent inflation. Not only are there very few scientists present, but there is no esprit de corps. There no longer are periodic seminars; there is distrust between administration and scientists; there is distrust between departments, laboratories, and other oceanographic organizations; and there are significant communication problems as mentioned above.

There clearly are impediments to a solution of their problems. The primary one is the financial situation, and this cannot be solved unless other sources of funding are found. There is little indication that the present government will relent in its nonsupport of the Academy of Science institutes, so the scientists are looking elsewhere for financial support. They are forming small companies, as in the other institutes I have visited. However, since this is an institute of the Academy, it has enough visibility in the West to possibly attract foreign investment, and this has been successful in a few instances as discussed above. It is not clear that anything will be done before nobody is left at this Institute.

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Valuable Oceanographic and Marine Meteorology Research at the State Oceanography Institute in Moscow

by J.P. Dugan

KEYWORDS: oceanography; marine meteorology; air-sea interactions; instrumentation; climate

INTRODUCTION

The State Oceanography Institute (GOIN, pronounced as two words) in Moscow is one of the largest of the (about) 20 laboratories managed by the Russian State Committee on Hydrometeorology. The thrust of the work at this Institute is to support the State Committee on Hydrometeorology on matters relating to oceanography. The State Committee has responsibilities similar to those of NOAA in the U.S., and this translates primarily to support of meteorological forecasts, both medium and long term; it also includes the support of surface wave and other forecasts for the ocean. As a result, the Institute has performed significant research on air-sea interactions in the Northern and Tropical Atlantic Ocean. It is located in the southwest portion of the center of Moscow, near the Park Kulture subway station.

The Institute was founded in 1943 for marine operations, including transport and movements of the military fleet. Its original tasks were to provide marine forecasts for tides, waves, and ice. Weather forecasts were already provided by the Soviet National Meteorology Center. The first director of the Institute, Professor Zubov, was a well-known scientist who has been called the father of Soviet oceanography. However, after he died, the level of science on oceanography steadily declined over the years until Dr. Sergey Lappo was elected director in 1986. He began contacts with organizations outside GOIN both within and outside of the (former) Soviet Union (FSU). He opened initial discussions with the Ministry of Science and Technology, and they now fund a reasonable percentage of the work at GOIN. This has enhanced the research content of the work, as their interests are more research-oriented than those of the Hydrometeorology Committee. At present, funding is largely provided by the State Committee, but additional funds are provided by the Ministry of Science and Technology for specific projects.

The remainder of this report provides a brief overview of the organization and facilities of GOIN, and a more detailed review of the research in physical oceanography and marine meteorology.

ORGANIZATION

The Director is Dr. Sergey Lappo, and the Deputy Director for International Affairs is Dr. Sergey Gulev who was the host for my visit. There are four departments.

The Department of Physical Oceanography and Ocean-Atmosphere Interactions is headed by Dr. Lappo. It has three laboratories:

- Ocean Climate & Marine Meteorology — Dr. Sergey Gulev
- Ocean Physics — Dr. Yugeny Kolukov
- Tropical Oceans — Dr. Oleg Nikitin.

The Department of Chemical Oceanography is headed by Professor Semen Oradovsky. It has five laboratories:

- Chemical Methods — Prof. Oradovsky
- Hydrochemistry of Enclosed and Semi-enclosed Seas — Dr. Andrey Tcitcarin
- Damping (Diffusion) — Dr. Ygeny Borisov
- Modeling of Oil Behavior — Dr. Sergey Ovsienko
- Environment — No name provided.

The Department of Regional Oceans is a small department headed by Dr. Vitaly Bortnik. It has two laboratories:

- Hydrology of Seas — Dr. Bortnik
- Estuaries — Dr. Vadim Polonsky.

The Department of Applied Oceanography was headed by Dr. Valeriy Kalatchkiy, but he recently took a position as a Deputy Minister in the Committee of Hydrometeorology. Doctor Aleg Zilberchtein was the Chief Scientist for many years in this department, and he is acting Department Chief. Its future apparently is uncertain, pending the appointment of a new chief, due in part to a perceived too-strong bias toward applications. The Department has several laboratories and groups:

- Laboratory for Wind Wave Processes — was Dr. Zilbertchein
- Laboratory of Data Assimilation — presently vacant
- Group for Wind Waves — Prof. Matchtochevsky
- Group for Tide Tables — Dr. Galena Soverchshaeva
- Group for Long Waves (surges) — was Prof. Vladimir German, but he has left and the position is vacant.

The Laboratory for Data Management is headed by Dr. Igor Zemlyanov. The Computer Center is headed by Dr. Vladimir Sokolov. Finally, the Laboratory for Ocean Techniques is headed by Dr. Georgiy Chikviladze. This laboratory is not held in high esteem by scientists in the laboratories, and Dr. Gulev felt that it has not been at all effective in supporting the progress of either ocean or atmospheric observations by the scientists of the Institute. Finally, there is a library, and Dr. Gulev felt that it provides the necessary access to Western literature. Apparently, they subscribe to half a dozen journals and provide Xerox copies of them to other institutes, while other institutes provide them with copies of the journals that they do not receive.

LABORATORY FOR OCEAN CLIMATE AND MARINE METEOROLOGY

As noted above, this laboratory, headed by Dr. Sergey Gulev, is in the Department of Physical Oceanography and Ocean-Atmosphere Interactions. This laboratory is an active one that has performed significant analyses of the large databases accumulated over the years by the large observational programs undertaken by this and other FSU institutes. It has 15 people, mostly scientists with Ph.D. degrees. There are two groups: air-sea interaction processes headed by himself, and physical oceanography led by Dr. Vladimir (Bob) Tereschenkov.

The objectives of the work in Gulev's group are to parameterize synoptic processes to provide necessary information for both improved models for mid-range weather forecasting and for models of climate change. They work with other scientists within and outside Russia, so they are reasonably familiar with research and development elsewhere on similar problems. Data from the many years of surveys undertaken by themselves and by other institutes in certain locations in the ocean is invaluable for this effort.

These surveys were intended to resolve the ocean mesoscale in these areas, so they are appropriate for studies of air-sea interactions on the "synoptic" scale. The idea is to understand the processes that drive the fluxes of heat, momentum, and moisture between the ocean and the atmosphere in these regions, and to use the information to estimate parameterizations for larger scale models that do not resolve these mesoscale processes. In this, they are being reasonably successful.

It was interesting to learn from Dr. Gulev the history of their work in this area. It started in the 1970s when Academician Marchuk was head of the Numerical Mathematics Institute of the Academy of Sciences, and more importantly, also the president of the Academy. He had results from a numerical weather model at his Institute that he interpreted to prove that local key regions in the ocean control the weather of Europe and Asia. He enlisted all the oceanographic institutes in the former Soviet Union to initiate a long-term program of repeated surveys of these areas. This effort became known as the SECTIONS program. Specific regions of the Norwegian and Greenland Seas were to be surveyed by AARI (the Arctic and Antarctic Research Institute in St. Petersburg), the Newfoundland Basin by GOIN, the Gulf Stream by IOAN (the Shirshov Institute of Oceanology of the Academy of Sciences in Moscow), the Guinea Current by MHI (Marine Hydrophysical Institute in Sevastopol), and the Kuroshio by the Far East Branch of the State Oceanography Institute located in Vladivostok. The institutes agreed to survey these regions on at least a seasonal basis for as

long as necessary to accumulate the data that the modelers said they required.

This work began in the early 1980s. It continued until the financial difficulties emerged several years ago and this enormous effort could no longer be afforded. Some institutes like the Hydrometeorology laboratories built strong survey capabilities, and they carried out a comprehensive program of surveys. GOIN had more than 30 cruises in the Newfoundland Basin from 1981 until 1988, and the effort was reduced gradually until their ships were seized by the Ukraine two years ago. Each cruise attempted to occupy 105 stations along 7 sections from the Newfoundland Ridge southward across the North Atlantic Current. Each station was from the surface to 2000 meters, with 30-mile spacing along the sections and 60 miles between them. Each survey took about 20 days and was repeated more or less seasonally. The high percentage of data recovery is remarkable, given the rough weather conditions that often are experienced in this area for a good fraction of the year.

As an aside, MHI also completed a long series of surveys in the Guinea Current that they extended to include practically the entire Equatorial Current all the way across the Atlantic. They did this because they found that significant fluxes occurred across a more extended area than just the local area projected by Marchuk. Of course, we know now that the remaining vast areas of the ocean have very significant effects on the atmosphere, even though the fluxes per unit area are much smaller. The other local areas were covered much less extensively. For example, IOAN has had a number of cruises to the Gulf Stream region, but they have been oriented much more toward research than survey, and consequently they are neither extensive nor complete. Doctor Gulev feels that Shirshov cruises that have been undertaken for the SECTIONS program have not really contributed to the goals of that program.

Well, in the meantime, the world oceanographic community discovered the importance of the ocean on climate change, and many institutes have entered the fray and joined national and international programs to learn the role of the oceans in this problem. These efforts are reflected in programs such as WOCE (World Ocean Circulation Experiment) and ROCC (Role of the Ocean in Climate Change), both of which GOIN actively supports. The ROCC program is a wholly Russian effort, and I obtained an English version of the planning document for it.

Returning to the research in Dr. Gulev's laboratory, he has been concerned with the problem of making accurate estimates of the fluxes of heat, moisture, and momentum on a regional scale. This is an important problem because the actual observations that can be made on a long-term basis clearly will have limited spatial resolution. They clearly will not resolve the much smaller spatial scales associated with the mesoscale variability in the ocean (and therefore in the marine boundary layer). The SECTIONS data in the Newfoundland Basin resolve the mesoscale variations, and Dr. Gulev has taken advantage of the ready availability of this data set for his analyses. The result shows the importance of having high-resolution measurements where the spatial and temporal scales are small, and he calculates the bias in the average (monthly and annual) heat and moisture fluxes when the observations are undersampled. He has published many important papers in the Russian literature in the last 5 or 6 years. They are in journals that are translated, namely *Soviet Meteorology and Hydrology* (the journal of the Hydrometeorology Committee), *Oceanology* (the journal of IOAN), and *Izvestia Atmospheric and Oceanic Physics* (reports of the Academy of Sciences). They follow the usual pattern of Russian papers in not providing sufficient detail on the techniques and instrumentation to satisfy most Western scientists, but they are quite good, nevertheless. Doctor Gulev presented a paper on the results of the above analyses to the most-recent annual Liege Colloquium on Ocean Hydrodynamics; this was well received by a knowledgeable audience since the focus of the colloquium this year was on sub-mesoscale air-sea interactions.

Doctor Gulev also has interesting, although somewhat controversial, results for meridional heat fluxes in the North Atlantic Ocean. These are recalculations based on annual databases of oceanographic data from GOIN and other institutes. One specific source of data is a set of more than 150 east-west sections across 36°N from Gibraltar to Bermuda and northwest across the Gulf Stream toward New York. The controversy is not new.

namely how best to estimate the north-south heat fluxes from individual sections that do not independently measure the velocity component perpendicular to the ship track. He interprets his results to imply a branching (bifurcation) of the fluxes into two classes, and infers that the ocean maintains one or the other of two stable states. This raises the question of what controls the states and what causes the transition of one to the other. The change occurs near 40-50°N so it is in the region of the Gulf Stream Extension, and he infers that it must be associated with states of the current system involving the North Atlantic Drift.

Doctor Gulev has another development that also is very interesting. He has developed a technique for estimating fluxes in the marine atmospheric boundary layer by using balloons tethered from research vessels. A radiosonde-type instrument package is attached to a helium balloon, and it is winched up and down repeatedly through the height of the boundary layer. This provides continuous vertical profiles of temperature, humidity, and velocity as a function of pressure. The volumes of the balloons are 6, 11, or 48 cubic meters, and they have a carefully designed aerodynamic shape. They have developed a simple but effective winch system that has a mechanism of sheaves for compensation of motion to enable its use during rough weather when the ship heaves a lot. To the best of my knowledge, this technique of using a balloon is unique, although a variant of it was used by U.K. marine meteorologists many years ago during the JASIN (Joint Air Sea INteraction) experiment. The idea and their implementation of it should be reviewed by a marine meteorology scientist. They have specific plans to use this in the SEMAPHORE experiment next year.

Other plans of this group are to occupy stations on WOCE section A3 at 36°N, and to make specific comparisons with similar sections occupied during the IGY (International Geophysical Year) in 1959 and by the research vessel *Atlantis* in 1981.

Doctor Gulev has succeeded in maintaining a program of working with a steady stream of students from Moscow State University. He was trained by the well-known oceanographer Academician Mamayev, and the close relations between the University and the Institute have been maintained.

Igor I. Zveriaev of this group is an example of this. He is finishing his dissertation on an analysis of interannual and seasonal variability in the atmosphere over a 15-year period. The data were made available from their meteorological data center (World Data Centre B) in Obninsk, and they include monthly averages for temperature, humidity, and geopotential for 5-degree squares over the Northern Hemisphere. Harmonic analysis enables the time series to be separated into interannual, seasonal, and residual "noise" components. They have a number of interesting results, including temporal plots of zonal average cross sections and maps at specific levels in the atmosphere of the amplitudes and phase of the seasonal coefficients of temperature and geopotential. Most interesting are the strong effects of humidity over the oceans at lower levels, and their seasonal and geographic propagation with time. This work has recently been published in a series of papers in *Izvestia Atmospheric and Oceanic Physics*, so it will be available in English.

Doctor Vladimir (Bob) Tereschenkov is the BOBA in their OMNET address GULEV.BOBA, and he works very closely with Dr. Gulev. He has been overseas (including the U.S.) and speaks better English than anyone I have encountered in Russia. His work has mostly been involved in analyses of the large data sets accumulated by GOIN over the years, both the Newfoundland Basin data set and the 36°N sections. To enable easy analysis by incoming students as well as his scientists, he has developed a very good software system for retrieval and analysis of T-S (temperature-salinity) data from the surveys. He showed me how easy it is to assemble temporary data sets, either geographically or temporally grouped from the whole set, to generate typical graphics, and to analyze them in a number of ways. It really is user-friendly, and practically anyone could be productive on it in no more than a day's time.

Doctor Tereschenkov had an interesting addition to the story associated with the SECTIONS data. He also felt that IOAN had contributed significantly to the program. In his view, IOAN was able to ignore Acad. Marchuk while Acad. Monin was the director of IOAN because of his strong base of independent power. However, when Acad. Monin was ousted in the mid-1980s, IOAN suffered because of the new director's (Dr Yastrabov) lack of influence. Because of the continuing support of SECTIONS by GOIN, they

received appropriate attention at high levels, and Dr. Lappo was able to acquire an increasing number of good scientists at GOIN.

As with most Russian scientists that I have met, Dr. Tereschenkov is very well trained, and he knows very well the problem of "seasonal" survey data sets that do not have any moorings or other data to connect them temporally. This is especially important, because they pursued the SECTIONS exercise without international cooperation so that they have not been able to take advantage of anyone else's data sets, either moorings or surveys. They have attempted to improve this situation by acquiring a capability to design and construct moorings, but this remains a capability they do not have. As an aside, the capability to design, set, maintain, and recover long-term moorings with subsurface floats has continued to elude not only GOIN but also all other FSU institutes. They simply do not have the infrastructure to produce the required quality of cable, floats, mooring design, etc.

Doctor Tereschenkov is interested in the stability of the anticyclonic eddy. This is an essential part of the circulation that occurs in the Newfoundland Basin, and its interaction with the associated current system, including the so-called North Atlantic Drift, Gulf Stream Extension, Labrador Current, and Azores Current. Thus, he is analyzing the interannual and seasonal variability in the water masses and the transition zone between them. He has an interesting way of calculating values of the T-S values of the water masses, which is important in their data, since they did not have the opportunity to collect data on their origins. He estimates average values by associating groups of T-S points by their gradients. He is, after all, also a student of Mamayev, who was a leader and has written a well-known text on T-S analyses. Research on the objectivity of this technique has been done by a student, Igor Yashaeyev. Then, Dr. Tereschenkov analyzes the temporal variability of these signals by separating the temporal series into interannual, seasonal, and residual components. They find the expected shift in values in the mid-1980s. He now is associating this shift with changes that other Western researchers have found in associated water masses (Labrador Sea water and Greenland Sea overflow water).

He also is analyzing the zonal sections along 36°N in the time period 1971-1981. The GOIN program that acquired these data was called "Long time period changes in hydrometeorological conditions in the North Atlantic." He uses Dr. Kirk Bryan's method to estimate the meridional heat flux, with the finding that it changed markedly in the mid 1970s from large to smaller values of the heat flux. Also, he finds that the change is contained in the Gulf Stream recirculation zone. This is interesting; however, he acknowledges that there is some controversy concerning his method of estimating the flux and also the limitation of the data that did not exceed depths of 2000 meters.

I also talked with Dr. Konstantin Belgaev who is a statistics expert in Dr. Gulev's laboratory from Moscow State University Department of Applied Mathematics. (By the way, it also seems to me that GOIN has a much greater mix of educational backgrounds in their oceanographic group than does IOAN, where practically all of the physicists were from the same department.) Doctor Belgaev is working on a data assimilation technique for the SECTIONS data in the Newfoundland Basin. He uses a more-or-less standard approach of minimizing the difference between the prediction of physical parameters by a dynamical model and the observational data. However, he has an interesting way of estimating the correlation functions based on the water mass analyses performed by the group. He constructs separate estimates for the fields of temperature and salinity from the observational data of the two primary and the transition water masses for each survey. He also models the full equations of motion, although his resolution is limited by computer power to 0.5 degrees in both latitude and longitude, 30 levels, and it encompasses an area of 10 degrees latitude by 15 degrees longitude. Thus, boundary conditions also are a real issue. As seems almost universal practice, he starts the model with the Levitus climatic data. He has difficulty with access to data on the surface fluxes that in part drive the motions because of

lack of good international connections, so he uses only climatic conditions for the wind stress and heat and moisture fluxes.

LABORATORY OF MATHEMATICAL MODELING

I went to a separate building to visit this laboratory headed by Dr. Sergey Ovsienko. It has about 10 people, and it is located about a 10-minute walk from the main building (toward the center of Moscow, in an incredibly decrepit and run-down building). The chief focus of this laboratory has been modeling oil spills. It is interesting that his main customer for this work is not his Ministry or even *in* Russia, but rather it is the Finnish Marine Science Institute in Helsinki. The contact there is Doctor Matti Lepperanto (OMNET: M.LEPPERANTO). The interest is in developing forecasting systems for the location and temporal evolution of oil spills when provided information on the initial location and extent.

Their modeling capability is unique in that the approach was driven by the smaller computational facilities that were available. They developed models that are quasi-three-dimensional. The oil spill model, for example, has a thin layer of oil on the surface that is subjected to forces of gravity, wind stress, currents, and losses resulting from evaporation and emulsion in the water. These forces are parameterized by relations that are generally available in the literature. The real saving is in the way the oil film is handled. They use a Lagrangian technique with a variable grid that follows the oil. Individual elements of the film are calculated as time evolves. This includes running summaries of the percentage of specific aromatic components of the oil. This is done by calculating the partial pressure of each component and then calculating the evaporation rate of them at each time step. They incorporate complicated lateral boundaries, including islands and coastlines. However, they apparently use a relatively crude algorithm for upwash on the beaches, as they have little information on the loss from the film due to this.

The model is easy to operate; it was demonstrated to me by Dr. Alexander Ivchenko who ran it for several specific cases. It is menu-driven, with a map of the specific location having previously been entered (manually at present). The operator enters the oil type from a number of choices, location of spill, volume spilled, type of spill (single point, multiple point, or continuous), and the environmental conditions. If an initial state is provided in the form of a photograph, they manually enter the outline. Otherwise it is assumed to be circular. As the calculation proceeds, the computer monitor exhibits the location, shape, and thickness (using colors) of the oil, as well as islands and coast in the vicinity. It is a reasonably good product, and it is called OSA (Oil Spill Accident system). As with other technologies that I have seen in Russia, major parts of this were done from elementary levels. For example, they had no software to assist in graphical displays, so the displays were all coded using C language graphics calls. The example I saw had a good replication of the coast of Finland and, just as on a chart, there are a large number of islands. As the oil in the simulation was swept past islands, it split into smaller patches, and these all behaved in a realistic manner. They claim to have several variants for the Baltic Sea, the Black Sea, and the Sakhalin Island shelf region.

During the Persian Gulf Incident, they saw the news items on the oil spill and went to work immediately on making a prediction of where it would go. They used rather coarse information for bathymetry and winds, a shallow water-circulation model from the Institute for Numerical Mathematics (Acad. Marchuk's group), and winds from their Hydrometeorological Centre. They claim to have finished constructing the model, run a simulation, and be on television with the results in three days. Temporal plots of the oil spill that they showed me are realistic, and compare favorably with maps constructed from observations that they obtained later from a NOAA publication. This is the fourth independent model of the Persian Gulf spill that I have seen to date.

They work on other types of modeling problems that have free boundaries. For example, they have a model of sea ice that can have multiple lateral boundaries. In the general formulation, it is identical to the oil spill model, but it uses a constitutive relation for ice. Doctor Ovsienko is reasonably knowledgeable about Western literature of a few years ago on both of the areas, although he was not familiar with the Preller ice model at the

Naval Research Laboratory (NRL) Stennis (Mississippi). He intends to combine these models so that he can simulate an oil spill among ice floes, as well as simulate oil on top or under a solid ice layer.

Doctor Ovsienko also showed me an interesting simulation of the evolution of an intra-thermocline lens. The model is similar to the oil spill model. It handles the boundary very well by using Lagrangian tracers, and it includes the full equations of motion in the lens, but only hydrostatic forces on the boundary. This latter assumption is unrealistic because it does not enable the radiation of energy away in the form of internal-inertial waves, as would occur in reality. Nevertheless, the simulations are interesting. He has results for a number of cases where the initial conditions for the lens shape were different. As the simulation proceeds, the lens collapses under gravity and spins up because of rotation, and then it oscillates at the inertial frequency through a large variety of axisymmetric and non-axisymmetric shapes. Energy and momentum are well conserved, as the lens continues to oscillate without diminishing.

Doctor Ovsienko is extremely well versed in techniques for someone so isolated from other modelers. He would like to extend his techniques to other cases of fluid motions with complicated boundaries. One that interests him is the case of large tidal amplitudes where extended mud flats dry out at low tide. He feels that his Lagrangian boundary method is a better way to model this situation than the Eulerian methods more typically used. His background is in mechanics, and he apparently has a long-running disagreement with the manner in which the scientists at AARI model the constitutive relation for sea ice. He also sees the need for assimilating observational data into the type of predictive models that he constructs. However, he was unable to clearly explain how he might go about it, although he obviously has given it considerable thought (including the use of photographs or other image data for oil spills for example).

None of the work discussed above has been published anywhere, and even their internal reports are few and far between. This is rather disappointing because I found that the three scientists I met (the two mentioned above plus Dr. Sergey N. Zatsepa) were all quite sharp, had a solid foundation in fluid mechanics, were good modelers, and had excellent computer skills on the 386 they used for the simulations. The technology they have built is not distributed beyond their group except in particular instances. Also, unfortunately for them, they cannot take advantage of recent capabilities that might be developed elsewhere because they do not have adequate communications. Doctor Ovsienko has a telemailbox (OMNET) in his name, but it is provided by the Finnish Institute for Marine Research, and he uses it only for communications with them. From what he said, he does not use it for the bulletin boards that are available on OMNET. The group appears to learn new things almost entirely from the published papers that they read. However, it is interesting how word gets around—he did know that the British Antarctic Survey in the U.K. had recently announced a new program in the mechanics of sea ice, and he enquired as to what it was about.

DEPARTMENT OF DYNAMIC SEA AND APPLIED OCEANOGRAPHIC PROBLEMS

This department is undergoing change as noted previously. The acting head is Dr. Oleg I. Zilberstein. He said that they were reorganizing and reducing their size to two laboratories and one group. He remains the head of the Laboratory of Applied Ocean Problems and expects to be elected department head. He thinks Dr. Lozovatsky will be elected to the head of a new Laboratory of Boundary Layers in the Ocean, and Dr. Alexander Beloshapkov (presently in Riga, Latvia) will be the head of the Group of Coastal Dynamics. The previous head of this department, Dr. Valery Kalatsky, is now vice chairman of the State Committee for Hydrometeorology.

Doctor Zilberstein said that they have several areas of expertise. They have done considerable work on modeling surface waves, surges, tides, and circulation in coastal regions and enclosed and semi-enclosed seas. They also have modeled the dispersion of pollutants in these marginal seas. He spoke of a model of the dispersion of radionuclides in the Southern Caspian Sea as a feasibility study for an Iranian nuclear power plant for the International Atomic Power Agency. His graduate work on modeling tide/surges was done while working at the Institute.

He has a group that models wind waves; it is headed by Dr. Gennady Matushevsky and includes Drs. Ilye Kaleatchenko and Vacheslaw Nadeev. They also provide services for shelf exploration for the design of oil and gas rigs and pipeline design. They have a large project at present on the conditions in specific polar regions for pipelines that will be built toward more southerly and western markets. These include what he believes is an interesting case of predictions of extreme events in the face of very little data for water levels, tides, currents, and waves.

He claims that they are the leading department in the country for research associated with problems on the oceanic shelves. They produce the tide tables for all Russian ports and for many foreign ones as well. This is done in the traditional way by using limited observations of tidal height to calculate the harmonic coefficients, and then projecting them into the future. They have had what he thinks was first-rate research in the area of three-dimensional models for tide/surges and circulation, but they have recently lost some of their better scientists to the West. He gave as examples Dr. German who now is in Israel, Dr. Sokolov who is in Australia, and Dr. Levekov who was the head of the Laboratory of Hydrodynamic Modeling.

They presently have tide/surge models for the Okhosh Sea and Bay, the Barents and the Southeastern Barents Seas, the Caspian Sea, the Assov Sea, Taganrod Bay, the White Sea and various bays off of it, and the Southern Kara Sea. The work in the Southern Kara Sea, in the Baydaratskaya Guba Bay in particular, is more than a surge study. It included many disciplines from many institutes in a study for design of a pipeline that will go under a wide bay that has a frozen bottom and is not covered with ice for only a few weeks in the summer.

They told me interesting stories of marine disasters caused by flooding from surges and tsunamis that were never reported in the press because of the suppression of negative news for many years. They feel that their long coastline is particularly susceptible to these disasters, yet there is very little interest in developing an operational prediction system to provide adequate warnings. This is only partly due to the scarcity of money, they believe, but rather it is due more to the long-held tradition that the Russians have had against providing warnings of dangerous conditions. Apparently, this view is changing only slowly, and the populations in the remote areas that are most at risk have no idea of the technology that could provide them with warning systems.

Doctor Vladimir Ryabinin helped translate the above information for Dr. Zilberstein, and he added some key information on the marine disasters subject. He is a Principal Researcher in the Marine Department of the Hydrometeorological Centre in Moscow, and therefore does not work for GOIN. He was present during our discussions because he is working on joint projects with Dr. Zilberstein. The Hydrometeorology Centre is the primary weather prediction facility for the country. He was a classmate of Dr. Zilberstein, and they are working together on the pipeline project crossing the Baydaratskaya Guba Bay of the Southern Kara Sea, among others. He showed me their reports on this project, and they were more than 8 inches thick in total. They apparently received a good deal of money for this work by a pipeline development consortium in the West and, as I have noted on previous occasions, they do not clearly separate this type of work from the work that they do for the institute.

Doctor Ryabinin is developing prediction models for operational use by customers of the Centre, namely shipping, fisheries, and the Russian Navy. They are working on models for sea surface temperature, sea ice, and surface waves. The meteorological input will be provided by the medium-range weather forecast model of the Centre, which is a copy of the model used by ECMWF (European Centre for Medium-Range Weather Forecasts) for the northern hemisphere. However, it cannot operate at the same spatial resolution as at ECMWF, nor is its data assimilation or accuracy as good because of their lack of computational power compared to ECMWF. The new marine system is called MMODAFS (Marine Meteorology and Oceanographic Data Assimilation Forecasting System). He provided many details, but an expert would have to talk with him to get it all. They are implementing a 2.5 generation wave model (just as the U.K. does, and I believe FNOC does), and they have a one-dimensional boundary layer model from the Numerical Mathematics Institute to provide better stability estimates for the stresses for

the wave model. They also will assimilate satellite-derived infrared images into their sea surface temperature model. It will not be eddy resolving; they do not see how they can get good enough estimates of the density structure without an altimeter as we will have. Finally, he felt that their operational predictions for the Northern Sea Route were the best source of data for those operations because the information from AARI was not as timely nor as operational.

Back to Dr. Zilberstein's Department, Dr. Matuchevsky briefed me on the work in his Wind Waves Laboratory. They have three primary efforts:

- model wind waves on the synoptic scale,
- calculate climatic wave conditions, and
- construct a preliminary model of a coupled wind and wave system.

The climatic calculations are in support of resource exploration and production platforms in the surrounding seas. The forecasting system is used by the Hydrometeorology Centre for their wave forecasts. It is relatively simple; it calculates only the mean square height, with a simple model for the shape of the spectrum. He says it is very similar to the GONO model used in The Netherlands. It has been tested and was published in the *Hydrology Journal* in 1991, which should be available in translation. Apparently, the tests have involved only visual observations from ships at sea. The model presently is used operationally for ship routing in the North Atlantic.

CHEMICAL OCEANOGRAPHY DEPARTMENT

The Laboratory for Pollution Monitoring is headed by Dr. Sergey Koryanov and has about 30 people. They measure the present water quality in estuaries, surrounding seas, and enclosed seas for the dual purposes of providing a status on them for the government and developing a system for effective monitoring. Data are usually collected by the local Hydrometeorology stations and sent to the Institute for analysis. A third effort is to use remote sensing data to study dispersion in these areas. They receive HRPT data from a system on an Academy of Sciences research vessel in the Far East. The specific pollutants they are interested in include hydrocarbons, phenyls, heavy metals, and pesticides, although oxygen and nutrients also are studied. They have no contacts with investigators nor with National Oceanographic and Atmospheric Administration (NOAA) personnel in the U.S., although what they do must be similar to some NOAA activities. They do have some contacts and coordinated work in an environmental monitoring program in the Baltic, and they have worked with other countries in the PEX86 (there is no name other than this one) and Skaggex programs coordinated by the International Commission on Exploration of the Seas (ICES) some years ago.

I also was briefed by Dr. Alexander Korchenko, a biologist in the Pollution Monitoring Laboratory. He has made observations on numerous cruises over 10 years at the Institute, both in the Baltic and the Pacific. He studies zooplankton, with a special interest in copepods. He is interested in their life cycle, distribution, population dynamics, and their aggregation or patchiness. He has made correlations of the patchiness with water physical and chemical structure. He recently spent a month at the Institut für Meereskunde in Kiel, and the stipend from there has enabled him to survive the present financial crisis. (He received a German salary in German marks, travel costs, and per diem. The Russian scientists that do this stay with friends, so they are able to save significant amounts of money for living costs in Moscow later on. He has a non-Moscow passport, and therefore must rent his housing at what are now extraordinary rates compared with salaries.)

I talked with a Principal Scientist in this Department, Dr. Vladimir Lapshin. He is the leader of about 10 scientists that work on miscellaneous problems of the thermodynamic and hydrodynamic structure of the upper ocean. He has worked on parts of SECTIONS and several POLYGON surveys, often as the expedition leader. In fact, he has spent almost half of his 10-year career at the Institute at sea on these surveys. He told me about his work during a recent POLYGON survey during January - March 1991 in the western Equatorial region. This was on one of the weather research vessels that GOIN operates from Odessa on the Black Sea (or used to, rather). The purpose of the cruise was to investigate the seasonal response of the Northern Equatorial and Counter Current zone

with dynamic, biological, chemical, and meteorological measurements. The most interesting result of this cruise was that they observed the Counter Current to be evident during this winter cruise whereas it usually is absent during the winter months. This occurred because the InterTropical Convergence Zone was farther south than usual, and he is writing a paper on this with Dr. Lappo. He did not know whether this event had been observed previously.

Doctor Lapshin is beginning work on the carbon cycle, and has obtained a large database from the World Data Center B in Obninsk of the available hydrodynamic and chemical data in the North Atlantic. His objectives are completely obscure to me, but he feels that these data are unique and the work will be a valuable addition to that being done in the West. Unfortunately, he does not have any direct contacts in the West, other than indirect ones on the ICES Committee of which Dr. Lappo is a member, so it is not clear that this will be complementary to work anywhere else in the world.

His group also has made numerical calculations of the fluxes at the surface of a two-dimensional plus time model of the surface layer, finding that the temperature dependence of viscosity strongly increases the fluxes when the surface temperature gets above 26°C. Although these results are written up in laboratory reports, none of it has been published in the literature, nor do they include any references to Western research in the area. He is not familiar with modern communications between scientists such as e-mail and has never heard of OMNET.

He has detailed calculations of the variability of the top meter of the ocean for scattering of light, including optical transients that specifically include lidar signals. In this work, he references work with Professor Vlasov, head of the Optics Laboratory of the Academy of Sciences Institute of General Physics, who apparently uses a lidar for remote sensing of the ocean. However, his model of the structure of the ocean surface layer is strange to me. He speaks of water motions that cause the scattering, but does not include realistic ocean surface elevations or bubbles, both of which I consider first-order parameters for light scattering and refraction in the ocean.

FACILITIES

The main building of the State Oceanography Institute is dilapidated, with no recent maintenance or repairs being evident, like most scientific institutes that I have seen. However, they do have computer facilities for the work that the typical scientist is engaged in. The building at the facility in Odessa is much newer, and it has as many scientists as in Moscow. It has been separated from the main institute because of the separation between Russia and the Ukraine, but most scientists there are Russian, and some communication and mutual work continues. Some hard currency is being made available from the Ministries so that some cruises are being undertaken and a few new instruments are being considered for purchase. However, during my visit, their hard currency account was frozen so that they were having trouble paying for a foreign port stop for an upcoming cruise. Apparently, it is not unusual at this time for the banks to freeze foreign currency accounts (even government ones).

They have six ships (all at the Odessa location), so they are embroiled in the political problems with the Ukraine. They are called "weather ships," and all are about 4300 tons. Ships include the *Passat* (oldest), *Musson, Victor Bulgayev, Georgy Ushakov*, and *Ernst Krenkel*. These are reasonably capable ships from what the scientists say, but they have poor instrumentation. The meteorological data are collected manually, and this is reasonably accurate for synoptic observations. The balloon instrumentation is adequate for the purposes of that instrumentation, and it would be interesting to see data acquired by that technology. The oceanographic instrumentation is very poor. The CTDs (conductivity-temperature-depth sensors) are built by the instrumentation institute of the Hydrometeorology Ministry in Obninsk, and the scientists readily admit that it is not up to Western standards. Standard instruments like the CTDs remain with the ship even in port, as do the technicians that operate and maintain them, so the scientist cannot even make sure that they have been calibrated before and/or after each cruise. The reversing thermometers and salinometers also are well behind the state-of-the-art, so the calibrations that the scientists are able to do at sea are not

really adequate for fine work. The problem is even more difficult in the case of chemical measurements than for the physical measurements.

This lack of calibration facilities causes a further problem for them in the way of international cooperation. The country does not, as I understand it, have a single calibration facility for these instruments that is up to the standards required for WOCE data, and therefore any data that are collected will not be accepted as part of that data set. And, they do not have the money to have the calibrations done elsewhere or to buy Western equipment for their ships. The WOCE cruise undertaken by a Shirshov research vessel in the Southern Ocean this last year, for example, had a full team of U.S. scientists and U.S. instrumentation onboard to make sure the data were up to standards.

At the moment, this is all academic, as the research vessels are tied up in discussions with the Ukraine as to who owns them. They are based at the former branch of the Institute at Odessa. The control of the military ships in the Black Sea currently is shared by Russia and Ukrainia, but the situation has not been resolved with respect to the research vessels. In the meantime, little money is available to run the ships in either country anyway, so they remain alongside in Odessa awaiting their disposal. They apparently will be offered for sale.

I was given a tour of the computer facilities by Dr. Vladimir Sokolov, head of the Computer Center. Desktop computers are scattered around the laboratories. They first obtained a 386 from a company (LabTam, I believe) in Australia 7 years ago, and it remains their file server. In the meantime, they have gotten many 286 and 386 machines, although some groups still have to share them among a number of scientists. The server has a gigabyte of disk storage and a 9-track tape drive, but the density is only 1600 bytes per inch so they have to request that any data from outside the country be written at this (now) outmoded density. They have an optical drive and LAN (local area network) software, but have not yet gotten them to work. The situation with their software is interesting; they universally use Norton Commander for file management, XEdit for editing programs, ChiWriter for word processing in English, and Grafor for graphics. Only the latter was written and is produced in Russia, apparently by the Institute of Mathematics. All others are commonly distributed without regard for copyrighting. This also applies to technical journals, as they are freely copied.

The communications of the scientists with the outside world are severely limited. The Institute has two OMNET mailboxes. One is named GULEV.BOBA, and it is managed by Dr. Gulev. It also is answered by Dr. "Bob" Tereschenkov (as noted previously). Doctor Ovsienko has a second one named S.OVSIENKO. The costs of both are subsidized by scientists or agencies in the West. Doctor Gulev will pass messages along to other scientists, but Dr. Ovsienko is reluctant to handle messages other than those directly related to his project with Finland. None of the scientists other than Gulev and Bob were familiar with the OMNET bulletin boards.

CONCLUSIONS

The State Oceanography Institute is in a better financial position than are the Institutes of the Academy of Sciences, and it is hiring some known scientists whereas the Shirshov is sharply reducing. This is apparent in both the number of scientists present in their offices and in the preparations for upcoming research cruises. Communications with the outside world of science is also better, but use is limited to a small percentage of the scientists. The Institute probably will survive the present crisis because its products are needed by the Hydrometeorology Centre for improvements of their forecasts, and these are needed by a large number of people.

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Policy

Support of Basic Science in Ukraine Linked to Country's Economic Survival

by Christine Glenday, Head of the National Science Foundation's Europe Office.

KEYWORDS: international collaboration; policy; salaries; science budget; reform

EXECUTIVE SUMMARY

One year after declaring independence in December 1991, Ukraine is plunged into a deep economic and political crisis, in large measure due to conditions inherited from the former Soviet Union. The ability of Ukraine to support its once flourishing scientific elite is directly connected to the degree of success the country will have in overcoming these serious obstacles.

On the other hand, during the last year, several significant changes involving science have been carried out by the government. In addition, a number of scientists have been appointed to top political positions.

A newly created State Committee for Science and Technology has instituted a wide reaching and innovative program of competitive grants for both basic and applied research. Although very rapidly implemented without the benefit of foreign peer review, it is an important first step, which has yet to take place in Russia.

The Ukrainian Academy of Sciences, after decades of domination by the former U.S.S.R. (FSU) Academy of Sciences, has declared itself autonomous from the government and has begun to move in the direction of decentralization. At the same time, inflation and lack of foreign currency have eroded much of its ability to support its top scientists, many of whom have left for the West.

The Ministry of Education, which includes among its responsibilities the distribution of the science budget to universities, has presented a plan to the government that recommends radical legal and financial reform in order to encourage scientific innovation. It has also demanded that universities provide stricter financial accounting for funds received from the Ministry for scientific research.

The university sector, however, has long been accustomed to its own system of "top down" distribution of research funds, and university rectors have been outspokenly opposed to the Ministry of Education's new policies. After decades of isolation from the Academy of Sciences, deliberately promoted by the government, universities have been hit even harder by the present financial crisis. Deteriorating laboratory conditions, as well as poverty-line student stipends, have resulted in a substantial drop in the number of students pursuing graduate degrees in science.

POLITICAL AND ECONOMIC BACKGROUND

Less than a year after Ukraine voted for independence by national referendum and elected Leonid Kravchuk, former Chairman of the Ukrainian Supreme Soviet, as president, the country faces an uphill battle against a crippling Soviet economic and political legacy. Among the almost overwhelming obstacles are: 100 percent inflation in 1992; severe gasoline shortages; a Parliament both inexperienced and largely uninterested in creating an economic infrastructure to encourage privatization; flagrant cases of government corruption involving private sales of the country's raw materials; tax laws that are strong disincentives to business development; complete lack of patent protection for individuals; lack of affordable food for the general population; a growing narcotics problem; and a notable rise in the number of suicides, particularly among young people.

President Kravchuk, a noted chess player who rose from relative obscurity to the presidency after

years of maneuvering through local Communist party politics, has just been forced to appoint a second prime minister, Leonid Kuchma, in less than 12 months. The first prime minister, Vitold Fokin, was strongly supported by Kravchuk. He was forced out of office after widespread public protests (including student demonstrations) that he actively blocked efforts toward economic reform while at the same time publicly stating his support for the development of a market economy.

Mr. Kuchma, a former director of the Soviet Union's biggest rocket factory (located in Dnepropetrovsk, in southern Ukraine), has wasted no time in persuading Parliament to grant him special powers for six months in order to carry out emergency economic measures. His plans include rapidly privatizing small enterprises and transforming large enterprises into joint stock companies. He has also announced plans for cuts in sales taxes, controls over wage increases, and a radical plan to reduce the current state of "runaway" inflation. Not surprisingly, one of his first acts in office was to fire the director of the Ukrainian Central Bank, a sign that he is clearly more action-oriented than his predecessor. He has gone so far as to state publicly that the country is in a state of "criminal mismanagement," in large degree due to an internal "Mafia", which has had wide access to government ministries.

In addition, the Ukrainian Parliament still contains a strong Communist "old guard", called the "Group of 239" out of a total membership of approximately 460. Since last year, the Parliament has passed an enormous number of laws, although little priority appears to have been given to the most pressing issues. For example, the Parliament has passed laws legalizing homosexuality and outlawing imported automobiles with steering wheels on the right-hand side. At the same time, critical legal issues, such as private property rights, bankruptcy, and tax reform have not been ad-dressed. Many laws that have been passed are enforced only on a haphazard basis. Widely differing political factions, combined with a lack of experience in the democratic process, have resulted in a lack of unity in Parliament that is critical to progress. Public apathy now toward Parliament is so strong that recent by-elections to fill 28 vacant seats resulted in voter turnout too low to validate almost half of the elections.

However, even a Parliament more dedicated to reform would find the fragmented economic legacy of the FSU a daunting prospect. The breakup of the FSU has had a devastating impact on all of the republics, which were previously linked through a common policy of "distributing" the assembly line process for industrial production. Although the Ukraine has managed so far to avoid some of the extreme internal and external conflict now occurring in other republics, those political disruptions have still had a serious impact on Ukraine's ability to obtain spare parts and other "assembly line" items for its large industrial enterprises.

Against these tremendous odds, it is not surprising that President Kravchuk has threatened to block ratification of the START strategic arms treaty unless NATO countries provide the Ukraine with military and economic assistance. Disposition of the substantial number of nuclear weapons still deployed in the Ukraine is a serious issue for the West and is an obvious bargaining tool for economic aid. This is particularly the case in view of Ukraine's widespread feeling that Western attention has been exclusively focused on Russia, thereby unfairly neglecting the needs of the Ukraine. Even worse is the perception, considered valid by many in the West, that both the U.S. and Western Europe are preoccupied with their own national economic problems and in general are giving little priority to the serious economic issues facing the former Soviet Union.

Although the country is in a difficult state, this is not the worst crisis in the history of the Ukraine, which lost more than 7 million inhabitants (some estimate as high as 12 million) in the very early 1930s through artificial famine created by Stalin's insistence on forced collectivization. In more recent history, the explosion at Chernobyl may cause long-term effects on the population that are far from evident at present.

Still, the extent of the current economy should not be underestimated, particularly given the population's widespread feeling that daily life was much better under the old Communist regime. The government clearly has more immediate priorities than maintaining the country's science enterprise, particularly basic research. On the other hand, scientists are at least represented at top levels of the present government. Doctor Ihor Yukhnovsky, a former director of the Ukrainian Academy of

Sciences Institute for Condenser Physics in Lvov, is one of Prime Minister Kuchma's six deputies, and is considered a "key democrat" in the senior ranks of government. At the same time, another of Kuchma's newly appointed deputies, Mr. Volodymir Demyanov, is a former Communist Party First Secretary. He has major responsibility for agriculture, as well as serving, oddly enough, as President Kuchma's Science Advisor.

Over the past year, the government has taken steps to encourage preservation of the scientific community. These actions, as well has other issues facing basic research in the Ukraine, are described in the following sections of the report. (NOTE: Approximate exchange rate in November 1992 was $1.00 = 400 rubles.)

UKRAINIAN STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY

Interview with Dr. Sergei M. Ryabchenko, Chairman

One of the first acts of the new Ukrainian government was to create a State Committee for Science and Technology, headed by Dr. Sergei M. Ryabchenko. His position is equivalent to that of a Minister for Science. Doctor Ryabchenko, a physicist, worked for many years at the Academy of Sciences. Prior to his appointment at the State Committee, he was an elected member to the former U.S.S.R. Parliament, where he served on the Parliament's Commission for Science. The State Committee itself consists of approximately 70 staff members, taken from various branches of the scientific sector, including the Academy, the universities, and the research institutes of the technical Ministries, such as the Ministries of Health and Environment. The Committee carries out a wide range of responsibilities, including the distribution of the civilian science budget, international and financial affairs, and the organization and management of a new series of national competitions for scientific grants.

The total civilian science budget for 1992 is approximately 30 billion rubles divided as follows: 7 billion to the State Committee, 8 billion to the Academy of Sciences, and 15 billion to the Ministry of Education and other technical Ministries.

Almost immediately upon formation, the Committee launched a dual program of competitive grants, one for basic and one for applied research. The first competition, which was for applied research, began in January and ended in April 1992. It was carried out in two stages: first, a competition for research topics, resulting in 250 selected out of 9000 proposed; and second, a selection of 2500 research proposals, out of 10,000 submitted. Approximately 4 billion rubles of the State Committee's budget were allocated to the applied research competition. Proposals were submitted by individuals, organizations, and even small businesses. The proposals were reviewed by a pool of about 3000 reviewers in the Kiev area, coordinated through a National Scientific Council composed of about 120 members.

The basic research competition took place from April to June 1992, and resulted in a final selection of about 1000 proposals, out of 5000 submitted. Approximately 750 million rubles were allocated to this competition. About 605 of the successful applicants came, not surprisingly, from institutes of the Academy of Sciences. The remainder came from the university sector (25 percent) and from research institutes of the technical Ministries (15 percent).

The applied research projects are currently being evaluated. In view of the critical degree of inflation in the country, funds are now insufficient to support projects originally selected. An evaluation of the basic research projects will take place in spring 1993.

Proposals in both cases are limited to a three-year period.

The sheer volume of proposals handled and the very short period involved for both competitions evoked inevitable protests in the research community of "too much reliance on an 'old boys' network." Still, the introduction of a competitive grants system is an important first step, for which Dr. Ryabchenko deserves enormous credit. In later interviews with scientific staff of the Academy of Sciences, the basic fund of the State Committee was repeatedly cited as a vital source of additional funding for Academy institutes.

Doctor Ryabchenko plans next to create an Innovation Fund, modeled after the National Science Foundation's Small Business Innovation Program. Doctor Ryabchenko's ultimate aim is to

increase government funding for basic research, and also to increase "post development research". He wants to decrease long-term institutional funding for applied research and to turn the "application" stage over to the private sector.

In addition to these competitions, the State Committee participates in an Intergovernmental Commission for the Support of Science. This Commission, established in December 1991, was formed to evaluate the degree of support that should be provided to major science programs in Ukraine, which previously had received heavy financial support from the FSU in such areas as high-energy physics, space, and robotics. These programs received about 2.5 billion rubles of the State Committee's 1992 budget. Other programs, more applied and industrial in nature, were integrated into the State Committee's applied research competition. In Dr. Ryabchenko's own view, the most critical problems facing Ukrainian science, basic as well as applied, are:

- Lack of hard currency for the purchase of equipment and supplies. This is linked with the overall lack of hard currency in the government, resulting from the current ruinous import/export balance.
- The need to develop priorities for scientific funding. The country simply cannot afford to support all fields of science. Economically, the country is facing the same decisions of what to produce domestically and what to import. After decades of authoritarian Soviet power, the need to develop Ukraine's own priorities is a new concept.
- Severe lack of legal infrastructure to encourage innovation (NOTE: the Ministry of Education was even more outspoken on this point);
- Lack of attention paid to the establishment of standards; and
- Overall lack of competitiveness afflicting all Ukrainian enterprises.

On the other hand, he felt that conditions for scientists in Ukraine are still slightly better than in Russia (i.e., relatively higher salaries), although he acknowledged that this might be a very temporary condition. The "brain drain" problem has affected the Ukraine somewhat less than Russia. One explanation is that Ukrainian researchers had less contact with the West, and therefore had fewer immediate job offers outside the country. However, Dr. Ryabchenko acknowledged that many of the country's top scientists have left the country. This has resulted in the dissolution of entire scientific schools, which is neither in the interests of the Ukraine or the rest of the world scientific community.

UKRAINIAN ACADEMY OF SCIENCES

Interviews with Dr. Rostislav M. Beloded, Director of Foreign Relations; Dr. Vladmir I. Skok, Vice President of the Academy; and Dr. Boris Stogny, Chief Scientific Secretary of the Academy

The Ukrainian Academy of Sciences, clearly the most important organization for basic research in the country, remains by its own admission a conservative organization, although significant changes have taken place within the Academy over the past year. From the Academy's point of view, this conservatism needs to be looked at in perspective, since Soviet political interference in scientific affairs has had some disastrous effects in the 20th century (e.g., the destruction of schools of genetics and physiology under Stalin and severe ecological problems resulting from policies promoted by Brezhnev, a land reclamation engineer by training). As late as 1987, the government proposed to reverse the direction of the rivers of Siberia in order to provide irrigation, much to the consternation of the general public. Fortunately, this plan was never carried out. The FSU government's decision to locate the Chernobyl nuclear facility a mere 100 kilometers from Kiev, Ukraine's capital city, was outspokenly opposed by the Ukrainian scientific community.

Established in 1918, the Ukrainian Academy traditionally was dependent on its "parent" organization, the Soviet Academy of Sciences for both funding and policy direction. This relationship resulted in considerable resentment on the part of the Ukrainian Academy. It was felt that the Soviet Academy unfairly preferred to give funding to build up institutes in Moscow and other parts of Russia, at the expense of the republics.

Even before Ukrainian independence was declared, the Academy declared its own "autonomy" from the government and insisted on complete independence in its internal affairs. (NOTE: In the view of the Ukrainian Academy, it has been much more successful in avoiding political interference in its affairs than has the Russian Academy of Sciences). Even though less funds are available now than in the Soviet days, an obvious nationalistic pride is evident at the Academy. President Kravchuk met with the Academy Presidium soon after his election; he listened supportively to the Academy's financial difficulties and proposed reforms. Doctor Sergei Ryabchenko, head of the State Committee for Science and Technology and responsible for distributing the civilian science budget, had a long affiliation with the Academy and has also noted the Academy's recent changes.

Although the government has maintained funding at about 85 percent of its previous level, inflation and lack of foreign currency have eroded the Academy's ability to purchase new instrumentation and spare parts, and some institutes have been forced to close down. Much to the Academy's outrage, foreign currency held for the Ukrainian Academy in Moscow was entirely appropriated by the Russian Academy after the formal dissolution of the Soviet Academy, despite the attempts of high-level Ukrainian Academy representatives sent to retrieve it. Fortunately, the Ukrainian Ministry of Energy provided $1.5 million from the sale of electricity to the Academy to purchase foreign scientific journals. Still, travel funds for international meetings are almost nonexistent, and as a result, there is a real feeling that Academy researchers are being essentially cut off from the world scientific community. Brain drain is a significant problem, particularly in the fields of biology, chemistry, and physics. Nevertheless, the Academy was accepted as a member of the International Council of Scientific Unions (ICSU) and is currently negotiating for membership in the International Union for Biological Sciences.

The Academy has been headed since 1962 by President Boris Paton, assisted by a Presidium consisting of a first vice president (Dr. Kukhar) and vice presidents elected for five-year terms. These include the Vice President for Life Sciences and Chemistry (Dr. Skok), the Vice President for Mathematics, Physics and Material Sciences (Dr. Trifilov), and the Vice President for Humanities and Archeology (Dr. Lukynov). The Academy also carries out research in computer sciences, engineering, and geosciences. Other Presidium members include the chief scientific secretary, heads of 11 departments, and 4 "honorary consultants." The Academy has 176 official Academy members, as well as 229 corresponding members, and 18 foreign members.

Doctor Paton, according to Academy staff, has moved the Academy in the direction of decentralization in the past years. The chief scientific secretary was given the task of essentially forcing this decentralization process through the Academy Presidium. Previously the Presidium had complete control over all appointments, including and above the "senior researcher" level—positions that also required Communist Party membership. Institutes now have autonomy to make these decisions, and also to directly control their involvement in international collaboration; this formerly was strictly monitored through the central administration of the Academy. However, according to the chief scientific secretary, difficulties still occur at the institute level regarding the distribution of funds to individual researchers.

At present, the Academy has a budget of approximately 8 to 10 billion rubles (depending on the calculation of the inflation), not including special funds received under the competitive grants programs of the State Committee for Science and Technology. The State Committee's funds are critical in maintaining research programs at a number of institutes, which have trouble surviving on the baseline Academy allocation. The Academy's budget is distributed among 132 scientific bodies, which include 100 institutes; 27 "filials", which are a step under a fully fledged institute; 13 small factories, which supply Academy institutes; and 5 centers for statistics. There are about 81,000 total staff; 47,00 are working in institutes, of which about 16,500 are "scientific workers". Included in this number are about 10,000 "Candidates of Science" and about 2,100 "Doctors of Science".

The Academy has the right to grant Ph.D.s (as do universities). Special scientific councils evaluate the Ph.D. candidates. When relevant to the research topic, they are assisted by representatives from universities and various ministry research

institutes. Approximately 2500 graduate students per year work in Academy institutes; only 700 to 750 complete their courses and go on to defend their dissertations.

MINISTRY OF EDUCATION

Interview with Dr. Vasily Kozorez, Deputy Minister for Education

Doctor Kozorez is the deputy to Minister Talachuk, with special responsibility for science. He has occupied his present position since April 1992, after having been for several years head of the Department for Cybernetics at the Academy of Sciences.

He began the interview by listing the three domains in which scientific research takes place in Ukraine: The Academy of Sciences; the universities and other entities supported by the Ministry for Education; and the research institutes of the technical ministries, such as Energy and Health. According to his statistics, 11 percent of the country's Ph.D.-equivalent scientific researchers are located at the Academy, 44 percent under the Ministry of Education, and the remainder under the other technical Ministries. On the other hand, the Academy receives almost one fourth of the total civilian science budget, a fact that causes some sensitivity in the other Ministries. Part of the difficulty lies in the inequity in salaries at the level of "scientific research" (i.e., those holding a Ph.D., but below professor or institute/department head level) in universities versus the Academy of Sciences.

Doctor Kozorev regarded the competitive grants programs of the State Committee for Science and Technology as a valuable source of additional government funding to universities, although in his view the very rapid implementation of the programs resulted in reliance on an "old boys" network. Also, he felt that it was far too soon for the State Committee to be asking for research evaluation.

He pointed out another aspect of the government's involvement in science funding, namely, a "priority list" of research topics that is suggested by the Parliament with input from the State Committee and others. As of October 1992, the following topics were on this list:

- Protection of the natural environment
- Health of mankind
- Agricultural production
- Energy saving technologies
- Ukrainian national studies
- New materials
- Information technology and automatization.

Doctor Kozorez regarded some of the topics (mainly natural environment, health, and Ukrainian studies) as being far too broad in scope to be considered real priorities. He did not believe that identification of scientific priorities of the country was within the competence of the Parliament.

Although Dr. Kozorez was quite critical of the "old boy" system influencing decisions on scientific funding, he admitted that the obstacles to overcome in both science and market development were severe: no government assistance to help innovation projects, no patent laws giving individuals commercial rights to their own discoveries, crippling taxes for individuals wishing to start their own businesses, a Parliament largely unqualified and uninterested in questions of market reform, a disorganized and corrupt national banking system that makes it difficult even for government institutions to have access to their own funds, and a national mentality that still equates market development with "speculation"—a criminal offense in the Soviet days.

On the other hand, he and Minister Talanchuk were given some official encouragement after a recent presentation to President Kravchuk, recommending that the president carry out a series of radical legal reforms and comparing Ukraine to a devastated Japan after the defeat of World War II. These recommendations included granting individuals patent rights, exempting from tax international funds sent to the Ukraine for scientific projects, more equitable distribution of the civil science budget among the Academy and the various Ministries, and correcting wage inequities among equally qualified scientific workers at the Academy and at universities.

In a move more directly aimed at correcting financial abuses at the universities, in June 1992 the Ministry issued an ultimatum to university rectors that they must sign specific contracts with university researchers when dedicated research

funds from the Ministry of Education are involved. This is to ensure that allocated funds actually reach the appropriate research teams, and also to ensure that individual researchers receive due intellectual property rights. Another requirement is that, in the event that research work supported with Ministry funds resulted in any profit-making enterprise, some degree of monetary payback must be given to the Minister. Doctor Kozorez readily acknowledged that this ultimatum had caused an uproar among university rectors, who were unanimously opposed to what they regarded as interference in their internal affairs.

KIEV UNIVERSITY

Interview with Professor V.A. Makara, Vice Rector for Research

The university sector in Ukraine, as in most of the FSU, was generally more politically dominated than the Academy of Sciences. According to Soviet government policy, "research" was to take place in the Academy and "education" was the responsibility of the universities. Up until the 1950s, there were very close relations between Kiev University and the Academy. Many of the heads of scientific departments at Kiev University also held top research appointments at the Academy of Sciences. Under Khrushchev, dual appointments in the Academy and the university were actually forbidden, under the concept that such alleged "double dipping" of salaries was bad for the economy. Researchers were forced to choose between the Academy and the university. Many top researchers did choose to retain full-time Academy positions; conditions for research there, in general, were more desirable (i.e., higher salaries), without the pressure of teaching students. As late as the early 1970s, laws preventing such joint appointments still existed. As a result, crucial links between the university and Academy research communities were lost. Predictably, the quality of teaching went down in universities at the same time that the Academy lost touch with many of the younger generation of scientists. Although some research did continue at universities, their laboratories were generally more poorly equipped. Now, attempts are being made to bridge this gap; for example, some branches of the universities are located at Institutes of the Academy of Sciences.

Kiev University, the most important university in the country, was founded in 1884. It has an undergraduate body of about 10,000 students and admits about 2000 students per year for the 5-year undergraduate course. In addition, there are 1000 postgraduates and a faculty of 2000 (of these, 300 have the Doctor of Science degree and 1500 have the Candidate of Science degree), divided into 18 large faculty groupings composed of 150 departments. Aside from the faculty, there is a staff of scientific workers (with Ph.D.-equivalent degrees) numbering about 2000.

The University runs two separate institutes: The Institute of Physiology and the newly created Institute for Ukrainian National Studies. The University also oversees the city's Botanical Gardens and has an Astronomical Observatory, with sites in the city and in the suburbs.

The University's budget for 1992 was about 1 billion rubles, of which 500 million rubles were spent on scientific research. About two thirds of this amount (350 million) came from the Ministry of Education. The remainder (150 million) came from the competitive research grants received from the State Committee for Science and Technology. (NOTE: During the interview, Dr. Makara made no reference to the necessity of administering contracts with individual scientific researchers when allocating Ministry of Education funds).

Doctor Makara listed the strong scientific areas of the university's research as: pure mathematics, theoretical physics, material sciences, and electronic materials.

One of the main problems at the university is keeping young people in science. Under the FSU regime, science was seen as a prestigious, well-paid profession, Now, far better salaries can be obtained elsewhere. Emigration is now relatively easy, and large numbers of students have left the country. About 10 percent of the university's graduate students are studying abroad, mainly in Poland, Hungary, and Czechoslovakia. Others have gone to France and the U.S. Another serious factor is the pitifully low level of student stipend, at 1000 rubles per month for an undergraduate and 1500 per month for an undergraduate. (NOTE: The current salary of a university professor is about 15,000 rubles per month).

According to Dr. Makara, there has been less brain drain in the faculty. Although the tenure system does not formally exist, there is a fairly "pro forma" system of reelection of the faculty every 5 years by the Supreme Soviet of the University. This Council consists of about 45 persons, including the rector, the 5 vice rectors, the deans of all the faculties, and some additional representatives from each faculty.

The University's most serious problem now is poor instrumentation; as a result, the strongest area of research in the University are such areas as pure mathematics and theoretical physics. Although the university has always been more poorly equipped than the Academy, current foreign currency shortages pose special problems. On the other hand, the Ukrainian Physical Society, in collaboration with the American and other overseas Physical Societies, have helped the University maintain subscriptions to foreign scientific journals, which would have otherwise not been possible with the foreign currency shortages

The rector confirmed that there were very few examples of international collaboration in science at the University.

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